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Journal of the ROYAL NAVAL SCIENTIFIC SERVICE

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CONTENTS

THE ROYAL FLEET AUXILIARY SERVICE

A Fleet Within a Fleet

SUMMARY

A full history of a service which celebrated its Diamond Jubilee in 1965 is beyond the scope of this article, but its history and development form the background to the present task of the RFA *Service.*

Although supplying the Fleet is a task as old as the Royal Navy itself—ships laden with stores and known as " pinks " accompanied the squadrons of Drake and Frobisher—it was not until steam replaced sail as a means of propulsion that the embryo RFA *Service was formed. In 1905, the first tanker, aptly named* Petroleum, *6600 dwt, was acquired and the first oiling at sea experiments were conducted in the following year with H.M.S.* Hindustan. *Two colliers,* Kharki (sic) *and* Mercedes, *were also in service and the former was converted into a fleet attendant tanker. After two years the* Petroleum *went into freighting service, bringing oil from America, Russia and the East Indies.*

Among other ships added to the service at this time were a store carrier and the Hospital Ship Maine, *2,816 tons (the latter had originally been fitted out for service in the Boer War by a Committee of American ladies headed by Lady Churchill, mother of Sir Winston Churchill. This vessel was the first of the hospital ships to bear this name, all of which were part of the* RFA *Service).*

Introduction

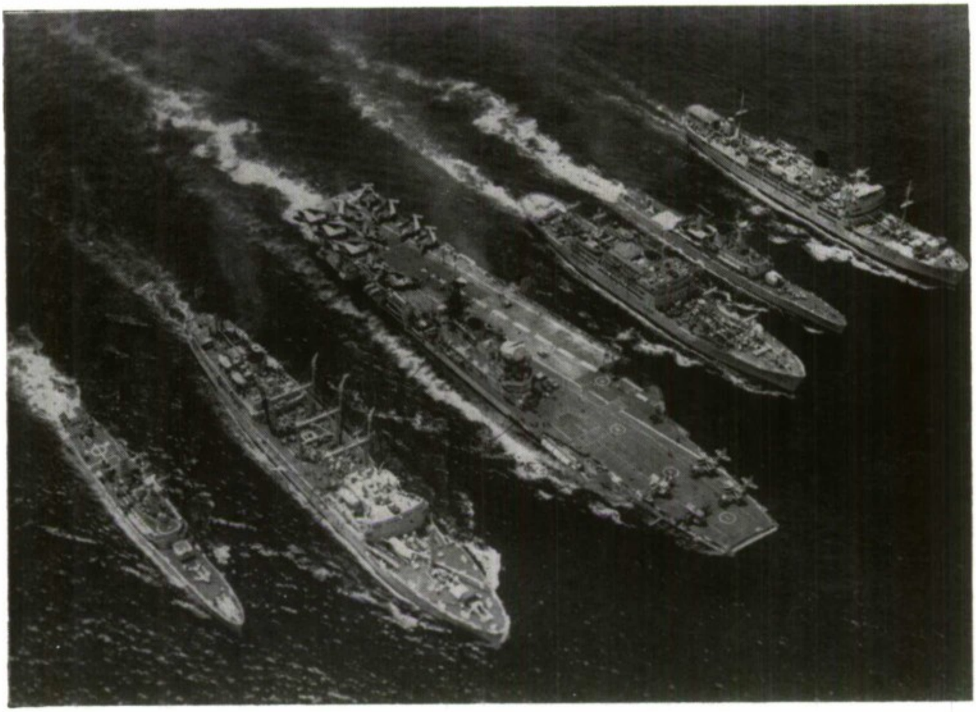
Recent Defence Reviews have indicated the increasing reliance of the Royal Navy on the concept of afloat support for the maintenance of its operational capability independent of shore bases. Vessels providing the afloat support replenish the fleet and provide it with mobile maintenance and repair facilities and ancillary services. Part of this role is performed by White Ensign ships such as Depot Ships, Maintenance and Repair Ships. The material logistic supply is the business of the R.N. Supply and Transport Service, and the vessels concerned are part of the Royal Fleet Auxiliary Service.

What is the basis for its status ?

Initially designated Fleet Auxiliaries, the term Royal Fleet Auxiliaries appeared in the Navy List of 1913. In 1911 an Order in Council was issued governing the registration of Government owned vessels, defining their legal position under the Merchant Shipping Acts. The statutory position of the *RFA* is based on this order and determines the " Merchant Navy " basis of this Fleet. *RFAs* fly the Blue Ensign with a plain upright yellow anchor in the fly.

How is it manned ?

Personnel of the *RFA Service* have always been part of the British Merchant Navy, serving under Board of Trade Agreements and National Maritime Board conditions as a minimum. The Royal Navy is unusual in having its front line logistic support ships manned by civilian personnel, and although this has been re-examined from time to time, it is accepted that the arrangement is effective in terms of money and manpower.



6 Ship R.A.S. off Hong Kong.
H.M.S. Minerva, R.F.A. Tideflow, H.M.S. Hermes, R.F.A. Reliant, H.M.S. Galatea, R.F.A. Retainer.

Early development

At the beginning of the First World War when the Royal Navy was predominantly a coal burning fleet, the *RFA* had eight ships. By the end of the war, oil was the main fuel and the growth of the *RFA* reflected this, as nearly 90 tankers were built or converted against less than 10 vessels of other types:—

(i) Amongst the tankers were Harbour Attendants and Escort Tankers
- 20—1000 ton OL Class (*Birchol, Hickorol, Teakol, etc.*)
- 10—2000 ton OL Class (*Rapidol, Serbol, etc.*)
- 6—5900 ton LEAF Class 16 knot convoy escort tankers (*Appleleaf, Brambleleaf, etc.*)

(ii) Freighting tankers
- 18—6/8000 ton LEAF Class (*Aspenleaf, Bayleaf, etc.*)
- 4—6/7000 ton OL Class (*Olcades* (British Beacon), *Oligarch* (British Lantern), *Olynthus* (British Star) and *Olwen* (British Light).)
- 22—5000 ton WAR Class (*War Bahadur, War Nizam, etc.*).

Some of the vessels were noteworthy for a number of reasons, *e.g. Dredgol* converted from a dredger; the fast LEAF Class referred to above built for convoy escort work. There was also the *Ruthenia*, built in 1900 as a liner (*Lake Champlain)*, taken up for service as a dummy battleship (simulating *King George V)* converted to a store ship and finally used as a tanker. After 20 years in the East she was raised by the Japanese after being scuttled at Singapore, refitted as a troop carrier and finally sold for breaking up in 1949.

The ancillary work of this mainly tanker service is typified by the first *Bacchus*—a small store carrier, and the *Perthshire*, a merchant ship built in 1893, taken over and used as a dummy battleship, served as the Coaling Officer's ship at Scapa Flow, and fitted out as a Fleet Supply Ship at Malta in 1925. This vessel served in turn under Red, White and Blue Ensigns.

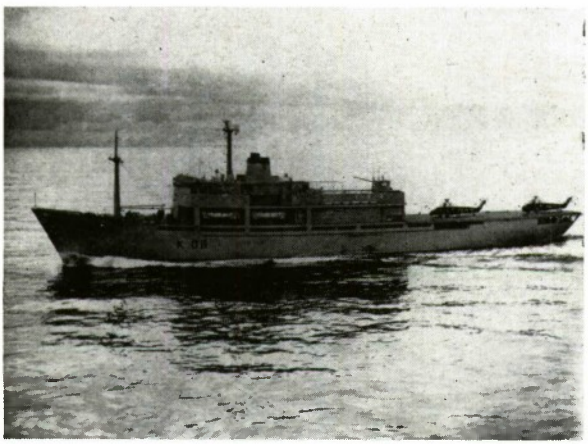
The Doldrums

For political reasons, the freighting tankers had been put out to commercial management under the control of Director of Transports which was incorporated into the Ministry of Shipping. The

operation by the Admiralty of its freighters through two "middlemen" was unsatisfactory and in 1921 it was ruled that these vessels should revert to Admiralty control but for a number of reasons the Director of Stores, Admiralty was unable to implement this decision until 1936.

After the war a large number were sold or disposed of and by 1921 the *RFA* comprised:

24 fleet attendants of 1000 and 2000 tons OL Class
6 fast freighters—LEAF Class
15 WAR Class freighters (built between 1918 and 1920 and included *War Afridi, War Bahadur, War Hindoo*)



R.F.A. Engadine, Helicopter Support Ship

4 OL Class freighters plus *Olna* and *Oleander*
3 Miscellaneous tankers (including *Ruthenia*)
3 PETROBUS Class spirit carriers
Hospital Ship *Maine* (ex *Panama*)

In 1936 the *Reliant* (formerly the *London Importer*) was acquired and converted into a Naval Store Issuing Ship and in 1937 a new *Bacchus* commenced service as a store carrier. No new tankers were taken over after 1922 until 1937 when six 11,500 dwt motor tankers were acquired. These became the first of the famous DALE Class and included *Abbeydale* and *Bishopdale*. Two more, *Cairndale* and *Cedardale* were added just before the outbreak of the Second World War.

Expansion during the Second World War

The first increase to the existing fleet was a further 10—DALE Class freighting tankers, of these, three, *Derwentdale, Dewdale* and *Ennerdale* were converted to "Landing Ships Gantry" each carrying 15 Landing Craft with military transport. They were used in the North Africa, Sicilian and Italian landings. The *Derwentdale* was damaged off Naples but towed to U.K. and re-engined. The other two served in the Far East. Six 3000 ton motor tankers of the Ranger Class (of which three are still in Service) were built in 1941.

At first the *RFA* tanker fleet was used mainly in a harbour fuelling role, but the development of fuelling at sea had continued and most of the LEAF Class Fleet Attendants and DALE Class freighters were fitted for underway replenishment by both the astern and abeam (trough) methods. This was given a further impetus by the capture, complete with oiling at sea equipment including buoyant rubber hoses, of the *Lothringen*, used by the Germans as a supply ship for *Bismark*. This vessel, an ex-Dutch Tanker, 10,800 grt, was taken into service as the *Empire Salvage* and employed ultimately in the Pacific Fleet Train. After the war she was eventually handed over to her owners and resumed her original name of *Papendrecht*. In the meantime a British type 5 in. buoyant hose was produced and trials were carried out in *RFA Eaglesdale* in 1942 leading to its fitting in some 46 *RFAs*.

With the creation of the Fleet Train to cope with the unprecedented logistic problems in the Pacific, a number of turbine tankers, fitted for replenishment at sea, were added to the *RFA* Fleet. These were built as EMPIRE Class freighting tankers with the then high speed (by commercial standards) of 15 knots. They became the WAVE Class and in all 20 were taken over of which three (*Wave Baron, Wave Ruler, Wave Chief*) are still in *RFA* Service. At about the same time a number of FORT Class (Canadian Victory Ships) were acquired for use as store issuing ships in the Fleet Train, and although initially manned and managed commercially as Merchant Fleet Auxiliaries, eight of these were subsequently converted to Royal Fleet Auxiliaries.

In 1945 the second *Olna*, a 12,600 grt 16 knot turbo Electric tanker, was built for service in the Pacific under the White Ensign. This vessel was transferred to RFA Service in 1946. This uncomfortable but well loved ship gave useful service until her sale in January 1967 for scrap.

During the war the *RFA* Service suffered the loss of 19 vessels and a further 16 seriously damaged. It emerged with a fleet of 74 vessels.

The post war years

Prolonged trials in replenishment of fuel at sea continued after the war in particular abeam fuelling by H.M.S. *Bulawayo* (ex the German *Nordmark*). To implement this experience in the light of the lessons gained off Korea in replenishment at sea procedures, eight WAVES were extensively modernised and fitted out for underway replenishment by arranging four derrick rigs in the after

well and increasing pumping capacity, and the first Fleet tankers to be designed as such entered Service in 1955/56. These were the *Tideflow* (originally *Tiderace), Tidereach* and *Tidesurge* (originally *Tiderange*) and, for the Australian Navy the *Tide Austral* (now H.M.A.S. *Supply*). These 13,000 grt tankers were fitted with automatic tensioning winches for tensioning the jackstay to facilitate abeam fuelling in rough weather. A new 6 in. rubber hose for higher pumping rates was introduced about this time.

R.F.A. Olmeda, Fleet Tanker

Trials of the underway replenishment of solids (stores, ammunition, food), and development of equipment had proceeded from about 1945 using firstly the 'Burtoning' method in use by U.S. Navy, and subsequently the Jackstay method leading to a decision to proceed with the development of the latter, using both light (1 ton) and heavy (2 ton) jackstays. The FORT Class Store Issuing Ships were fitted with 1 ton and 2 ton jackstay rigs, controlled by existing cargo winches. These vessels, however, were too slow and in 1954 and 1957 respectively the *Chungking* and *Changchow* (9400 grt), which had been built in 1951 for the China trade, were acquired and converted to Fast Replenishment Ships, being renamed *Retainer* and *Resurgent*. Also in 1957 the *Somersby* (8400 grt) was bought for Service and re-named *Reliant*.

1957 to 1967—the role changes

By 1957, the *RFA* Service had expanded from eight ships in 1914 to 113 including 17 tugs and salvage vessels and the R.R.S. *Discovery*. But many of the ships were old, the requirement for purely freighting vessels was reducing (many had been on charter to commercial interests for some years) and others were laid up in reserve. More importantly, few were capable of meeting the developing role of the *RFA* Service. Accordingly a considerable programme of new construction was begun to produce a more compact fleet, revitalised with purpose built ships, and personnel trained to meet the complex requirements of an underway replenishment auxiliary force. The freighting requirement was met by taking over 7 × 17,000 ton deadweight tankers from the trade in 1959. These vessels were named after the LEAF Class of earlier years and six are still in service as Support Tankers.

Many new vessels have been brought into service in the past few years, all with interesting developments. *Tidespring* and *Tidepool* (the first *RFAs* with helicopter flight decks, hangars and workshops) in 1963. *Olwen* (ex *Olynthus*), *Olmeda* (ex *Oleander*) and *Olna* (18,600 grt) the first *RFAs* with fully remotely controlled and data logged engines and auxiliaries in 1965/66, and in 1966/67, the three NESS Class (14,000 grt) Store Support Ships of the latest design for dry cargo underway replenishment, and two new Fleet Replenishment Ships *Resource* and *Regent* (of 19,000 grt) carrying mainly ammunition were brought into service.

Although not strictly in the replenishment role, mention must be made of the new *Derwentdale* (ex *Halcyon Breeze*), *Dewdale* (ex *Edenfield*) and *Ennerdale* (ex *Naess Scotsman*), three large tankers recently taken over for use as mobile reserve tankers. These are between 47,000/67,000 dwt, and are the largest vessels in *RFA* Service.

The *RFA* Service now comprises:

- 2 Fleet Replenishment Ships (*Regent/Resource*)
- 8 Store Support Ships (Re, NESS and FORT Class)
- 11 Fleet Tankers (OL, TIDE and WAVE Class)
- 3 Mobile Reserve Tankers (DALE Class)
- 6 Support Tankers (LEAF Class)
- 3 Small Fleet Tankers (RANGER Class)
- 2 Coastal Tankers
- 1 Helicopter Support Ship (*Engadine* commissioning October 1967)
- 3 Store Carriers
- 2 Coastal Store Carriers.

In addition there is a small but important branch of the *RFA* Service under the separate control of the Director General Dockyards and Maintenance (Marine Services Division) comprising:

- 6 Ocean Tugs
- 3 Harbour Tugs
- 3 Salvage Vessels.

Rover Class

A new class of small fleet tanker will enter service by early 1970 to replace the three remaining WAVE class vessels which are reaching the end of their useful lives. These vessels, each of 7,000 tons deadweight, have been named *Green*, *Grey* and *Blue Rover*, and have been specially designed to replenish H.M. ships at sea with fuel, fresh water, limited dry cargo and refrigerated stores under all conditions whilst underway. A helicopter landing platform is also provided, served by a stores lift, to enable stores to be transferred at sea by helicopter.

What of the future

Already the service is developing beyond the function envisaged in 1957. The extended use of helicopters has led to study and trials of vertical replenishment techniques. Many *RFAs* have helicopter decks, some have hangar and workshop facilities and two carry their own helicopter flight under an R.N. Flight Commander. *RFA* personnel are being trained in flight deck procedures, " air traffic control " of helicopters and associated techniques. Moreover the *RFA* Service now mans the *Engadine*, a helicopter support ship, specially designed for the training of R.N. personnel in helicopter work.

To return to the opening paragraph, the Royal Navy will increasingly rely for its direct logistic support on an *RFA* Service whose vessels and manpower are of the calibre to fulfil this task to the standard the Royal Navy has the right and has come to expect. The aim of the 1200 officers and cadets and 2,400 petty officers and ratings who man this section of the British Merchant Navy (of some 400,000 grt) is to maintain and improve upon this standard in the challenging period ahead.

TIN-POT OR JACKPOT—A MANAGEMENT DILEMMA

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My friend Danny was once asked to design an adaptive control system to maximise the production of a large industrial plant (glass or steel or something—I forget which). On investigation, the problem was found to have some curious features. Firstly, the prospective improvements in production were very small, say 0·5%, difficult in fact to detect in the 2% or so fluctuation due to variations in the raw materials. Secondly, the expense and effort involved was considerable, requiring a total investment of perhaps £500,000. And thirdly, the 0·5% increase in production was significant only by virtue of the extremely large scale of the plants, having an output worth say £100m. per annum. Thus even development costs of £500,000 would be recovered in a reasonable time if the output could be raised by 0·5%. Danny emigrated.

I once worked in a large research and development lab. A story (perhaps malicious) gained currency among the junior engineers that the head of one Division had been taken to task over the apparently trivial improvements which were in prospect in return for a sizeable development effort. The suggestion was that the barrel was

being scraped rather too vigorously. His reply, so the story went, was that since the research was to do with large scale electricity generation, the savings per annum on a barely measurable improvement in efficiency would more than cover the development costs.

It seems to be an occupational hazard of an engineer engaged on any defence work that sooner or later he will encounter the argument that although the increase in effectiveness due to some proposed modification or improvement is admittedly minute, its considerable cost is very small compared to that of the battleship (or even the consequences of losing the battleship).

The above anecdotes illustrate particular examples of what seems to be a general problem. It has quite distinctive features: its fundamental characteristic is that many orders of magnitude are involved. A vanishingly small return for a sizeable investment is " rescued " by an extremely large application coefficient, resulting in the apparently excellent return on development capital of perhaps 100% per annum. However, since this return is invariably added to the extremely large basic sum, its very presence may often be difficult to prove or disprove.

If a general problem can be isolated, it is an attractive prospect to find some general solution to assist in handling particular examples which may occur in the future. In the examples quoted the returns for the effort seem to be reasonable on one basis, yet one feels intuitively that there must be something wrong with the argument. In order to examine the situation more closely, let us begin by defining a MERIT function for some proposed development A:

$$\textbf{Merit A} = \frac{\textbf{Return on Investment in A}}{\textbf{Cost of A}}$$

$$= \frac{\textbf{(Efficiency Increase due to A) (Total Investment)}}{\textbf{Cost of A}}$$

In our general problem, the *Efficiency Increase* is vanishingly small, but this is balanced by a very large *Total Investment*, resulting in some fair value for Merit (A).

To enable us to consider alternative courses of action, it is necessary to include a further term in the *Merit* function definition, to express the probability of actually achieving the efficiency increase from the proposed development. This will be written as (*Prob. Achiev. A*), so that

$$\textbf{Merit (A)} = \textbf{(Prob. Achiev. A)} \times \frac{\textbf{Efficiency Increase due to A}}{\textbf{Cost of A}} \times \textbf{(Total Investment)}$$

If two different proposals A and B were competing for limited available research funds, a reasonable basis for selecting proposal A would be if *Merit* (A) were greater than *Merit* (B), and vice versa.

$$\textbf{Thus if } \frac{\textbf{Merit (A)}}{\textbf{Merit (B)}} > \textbf{1, choose A; otherwise choose B}$$

Consider now how this formulation could be applied to a hypothetical case to do with the large-scale generation of electricity. Proposal A has prospects of marginally increasing the efficiency of turbines, say by 0·5%. Proposal B is a very advanced but somewhat harebrained scheme which, if successful, could increase the overall output by perhaps 50%. Both of these schemes require much the same funding, and would have application to the same total investment. Thus the *Merit* ratio reduces to

$$\frac{\textbf{Merit (A)}}{\textbf{Merit (B)}} = \frac{\textbf{(Prob. Achiev. A) (Efficiency Increase due to A)*}}{\textbf{(Prob. Achiev. B) (Efficiency Increase due to B)}}$$

(Note that the large investment factor has cancelled out).

Introducing numbers, proposal A might be *judged* to have a 98% chance of achieving its 0·5% increase in turbine efficiency, whereas proposal B might be *judged* to have, say, a 5% chance of working and achieving the 50% increase in output.

$$\textbf{Thus } \frac{\textbf{Merit (A)}}{\textbf{Merit (B)}} = \frac{0{\cdot}98 \times 0{\cdot}005}{0{\cdot}05 \times 0{\cdot}5} = \frac{0{\cdot}0049}{0{\cdot}025}$$

$$\therefore \frac{\textbf{Merit (A)}}{\textbf{Merit (B)}} = 0{\cdot}2 \quad \therefore \textbf{ Choose B}$$

In this rather extreme example it would therefore appear, on the information supplied, to be five times more rewarding to accept the more uncertain but potentially more rewarding project B (the factor of 5 relates of course to the average behaviour over a large number of similar situations, rather than to any one decision on its own).

* This formulation has features similar to those found in statistical decision theory.

In the case of Danny's industrial plant, or in some defence applications, it might well be decided on similar reasoning to the above that the money could be better spent say in setting up a " think-tank "; engineers would be paid just to sit around and think of ideas as to how a *substantial improvement* in productivity might be achieved. A fairly low success rate is likely to result from such an operation, but a point can be reached when even one good idea in a hundred would bring a higher overall return for the resources employed. The " think-tank " is not a novel suggestion, but it is put forward as one of the more extreme alternatives which might attract development funds in preference to some of the above examples.

Summary

It has been argued that when some proposed marginal increase in the efficiency of a system is made worthwhile only by virtue of the extremely large fixed investment involved (or perhaps large costs or dire consequences of failure), it is not safe to use a narrow criterion based on expressing the expected return as a percentage of the improvement costs. The criterion should be expanded so that a particular project should be accepted only when it has been compared to all available and properly weighted alternatives. This should avoid the absurdity of paying substantial sums for vanishingly small improvements; it seems likely that once the prospective improvement reduces to the same order as the inherent fluctuations in the system, some alternative of the "think-tank" type begins to be a serious contender—trying for the *Jackpot* becomes a better proposition than achieving the *Tin-Pot*.

Should this note fail to raise some discussion, it will confirm the writer in his unease that he has indulged in the public laying of a private ghost.

USE OF TRANSIENT EXCITATION IN THE DYNAMIC ANALYSIS OF STRUCTURES

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ABSTRACT

This study demonstrates that transient methods of measuring the frequency response of structures may be used advantageously now that the digital computer is established as a means of analysing transient data and the accuracy of steady state methods can be preserved. The use of single pulse and rapid frequency sweep excitation is investigated and the swept sinewave is shown to be the most suitable forcing transient for structural testing because of the control available over its spectral properties.

Introduction

In recent years many methods have been proposed for the measurement of the frequency response of linear systems but the method most often used in the study of structures is the steady state vector response method[1], the natural frequencies and damping ratios being measured from the resulting vector diagrams. This method is tedious and time consuming and often cannot be readily applied outside the laboratory. Some effort has been directed in the past to employ quasi-steady state methods such as the slow frequency sweep technique[2] but errors are introduced because the response at resonance is less than the steady state maximum and the frequency at which the maximum occurs is shifted in the direction in which the excitation frequency is changing. Additional errors are introduced in the analysis of the system response because of the necessary averaging time of the function analyser used to derive the vector

diagrams. Some refinements in technique have been proposed by Reed[3] who developed the 'λ Law' frequency sweep in which the percentage change in frequency per cycle is constant. This offers some reduction in test time when compared with logarithmic and linear frequency sweeps but a knowledge of the minimum damping likely to be encountered at any resonant frequency within the sweep range is essential in order that the method may be employed advantageously.

Transient methods of measuring frequency response have considerable advantage over the steady state and quasi-steady state methods because of the extremely short test time but transient test techniques have not been employed widely in structural studies because of the difficulty of analysing the data in all but the simplest cases. The availability of a digital computer[4] to derive the complex frequency response function from transient test data by carrying out the Fourier transformation of the digitized excitation and response time functions means that transient methods may now be used. This paper discusses the choice of suitable forcing transients and demonstrates how transient methods may be applied to simple structures, the test results being compared with calculated frequency response characteristics and those measured in steady state tests.

Frequency response from the impulse response

The frequency response function $H(i\omega)$ of a linear system subjected to transient excitation $x(t)$ which produces a response $y(t)$ is given by

$$H(i\omega)=\frac{Y(i\omega)}{X(i\omega)} \qquad \ldots (1)$$

where $X(i\omega)$ and $Y(i\omega)$ are the Fourier transforms of $x(t)$ and $y(t)$ respectively.

i.e.

$$X(i\omega)=\int_{-\infty}^{\infty} x(t)e^{-i\omega t}\,dt$$

and $\qquad \ldots (2)$

$$Y(i\omega)=\int_{-\infty}^{\infty} y(t)e^{-i\omega t}\,dt$$

If $x(t)$ is a unit impulse applied to the system at $t=0$ then $X(i\omega)=1$ for all ω and

$$H(i\omega)=\int_{0}^{\infty} h(t)e^{-i\omega t}\,dt \qquad \ldots (3)$$

where $h(t)$ is the impulse response function.

For a linear single degree of freedom, mass-spring-damper system

$$h(t)=\frac{\omega_n}{\sqrt{1-\zeta^2}}\,e^{-\zeta\omega_n t}\,\sin\sqrt{1-\zeta^2}\,\omega_n t \qquad \ldots (4)$$

where ω_n = the undamped natural frequency
ζ = the viscous damping ratio.

Whence from (3) and (4)

$$H(i\omega)=\frac{1}{\left(1-\frac{\omega^2}{\omega_n^2}\right)+i2\zeta\frac{\omega}{\omega_n}} \qquad \ldots (5)$$

which is the complex frequency response function.

In principle, equation (3) could be used to determine $H(i\omega)$ from a measured impulse response function but in practice, truncation of the impulse response function occurs, either because the decaying signal becomes immeasurable or because the analysis time is limited and a finite upper integration limit τ_m is introduced. The effects of truncation have been investigated by Clarkson and Mercer[5] who showed that the resonant frequency may still be identified from the vector diagram as the frequency at which the rate of change of arc length with frequency, $\frac{ds}{df}$, is a maximum but that the damping measured from the diagram derived from the truncated time function will be greater than the true value. It may be shown from the theoretical analysis by Clarkson and Mercer that the percentage error in ζ produced by truncation is:—

$$E\%=100\left\{1-\left[\frac{1-e^{-\zeta\omega_n\tau_m}(1+\zeta\omega_n\tau_m+\frac{1}{2}\zeta^2\omega_n^2\tau_m^2)}{1-e^{-\zeta\omega_n\tau_m}(1+\zeta\omega_n\tau_m)}\right]\right\} \qquad \ldots (6)$$

which is plotted in Fig. 1, where $f_n=\frac{\omega_n}{2\pi}$, and shows that if $\zeta f_n\tau_m>1$, the error in the measured value of ζ is less than 5%. Hence in structural testing it should be possible to attain a high degree of accuracy without the need to analyse extremely long response records. For example, if $f_n=100$ Hz and $\zeta=\cdot005$ then only 2 sec. of data need be analysed to achieve the condition $\zeta f_n\tau_m=1$.

Transient excitation in practice

It has been shown in Section 2 that the frequency response function may be obtained from the response of a system to a unit impulse. Unfortunately the unit impulse is unattainable in practice. If the division indicated in equation (1) is performed there is little limitation on the choice of forcing transients but the concept of impulsive excitation logically tends to lead towards the use of a single pulse of simple geometric shape and sufficiently short duration that the pulse approxi-

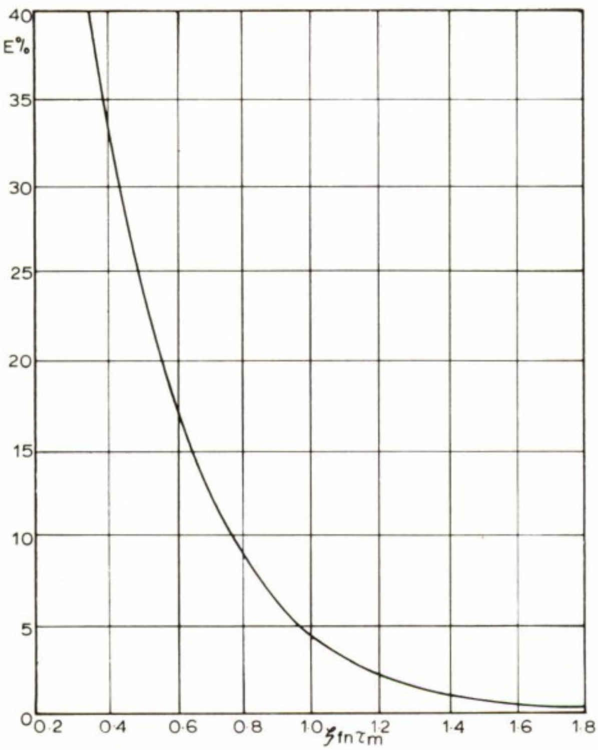

FIG. 1. % error in ζ produced by truncation.

mates closely to an impulse throughout the frequency range of interest.

Consider the symmetrical trapezoidal force pulse defined by

$$\left.\begin{array}{lll} 1. & F=\dfrac{F_o}{t_o}t & 0<t<t_o \\ 2. & F=F_o & t_o<t<(\tau-t_o) \\ 3. & F=\dfrac{F_o}{t_o}(\tau-t) & (\tau-t_o)<t<\tau \end{array}\right\} \quad \ldots (7)$$

where τ=pulse duration

t_o=rise time=decay time

$$F(i\omega)=\int_0^\infty F(t)e^{-i\omega t}\,dt \quad \ldots (8)$$

By superposition

$$F(i\omega)=F(i\omega)_1+F(i\omega)_2+F(i\omega)_3 \quad \ldots (9)$$

whence it may be shown that

$$|F(\omega)|=\frac{4F_o}{\omega^2 t_o}\sin\frac{\omega t_o}{2}\sin\frac{\omega(\tau-t_o)}{2} \quad \ldots (10)$$

and $$\phi(\omega)=-\frac{\omega\tau}{2} \quad \ldots (11)$$

where ϕ is the phase angle (relative to the zero frequency component), which is shown to be independent of pulse shape.

Thus

$$\frac{d\phi}{df}=-\pi\tau=\text{constant for a given pulse} \quad \ldots (12)$$

From (10) it may be seen that for a rectangular pulse

$$|F(\omega)|=\frac{2F_o}{\omega}\sin\frac{\omega\tau}{2} \quad \ldots (13)$$

and for a triangular pulse

$$|F(\omega)|=\frac{4F_o}{\omega^2 t_o}\sin^2\frac{\omega\tau}{2} \quad \ldots (14)$$

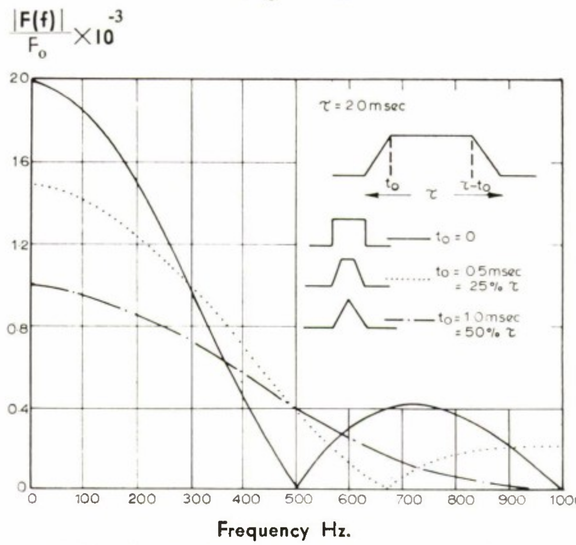

FIG. 2. Modulus spectra of rectangular, symmetrical trapezoidal and triangular pulses

The modulus spectra are shown in Fig. 2, whence it can be seen that as the rise and decay times increase from the rectangular through to the triangular pulse the frequency range to the first zero in the spectrum increases but the overall spectrum height decreases. The latter effect is produced by the reduction in pulse area which governs the spectrum level at f=0. It is evident in Fig. 2 that if the pulse duration is short compared with the period of the system under test the pulse approximates to an impulse. If the system is lightly damped then it is probable that little error would be introduced into frequency response measurements by analysing the response only and this is confirmed in Fig. 3 which illustrates the results from a pulse test on a single degree of freedom system, presented in modulus and phase form for comparison with the pulse spectrum variations described later.

The investigation of a single degree of freedom system was carried out by measuring the response of a free-free beam in its fundamental mode, the responses in other modes being assumed to be negligible throughout the frequency range of

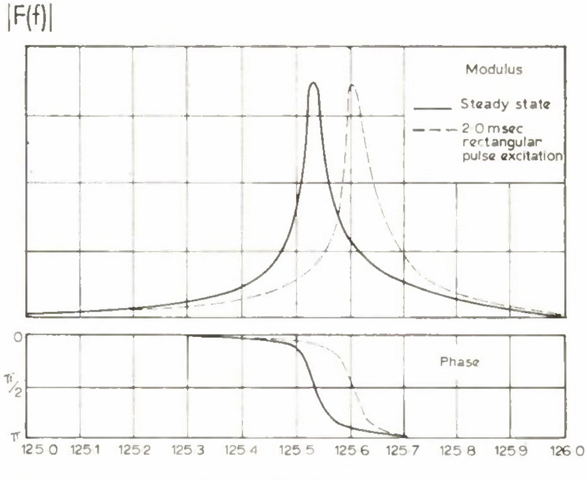

FIG. 3. Response of free-free beam in fundamental mode by steady state and transient excitation.

interest. The beam was excited by a 2 msec rectangular pulse applied at the mid point of the beam through a coil which protruded into the field of an annular permanent magnet, thus forming a vibration exciter. The response was measured from a strain gauge at the mid point, the amplified output voltage being recorded and subsequently transformed by computer after analogue to digital conversion. The results are summarized in Table 1. The calculated variation in the modulus and phase spectra of the 2 msec rectangular pulse through the range 125 Hz to 126 Hz are $-0{\cdot}22\%$ and $0{\cdot}80\%$ respectively of the values at 125 Hz, thus the effects of the variations near the 3 dB points are negligible and the assumption that the response only need be analysed is justified in this case.

Table I

The fundamental mode of the free-free beam

Derivation	f_n	ζ
Calculated	125·70	–
Steady State	125·53	$1{\cdot}39\times10^{-4}$
Transient Test	125·60	$1{\cdot}48\times10^{-4}$

The following disadvantages which are generally applicable to pulse excitation are apparent:—

(a) If the pulse is made to be of extremely short duration so that the excitation may be considered as 'impulsive', the energy levels of the excitation and response may be so low that measurements may not be made with reasonable accuracy.

(b) If pulse excitation of multi degree of freedom systems is considered the technique is not selective. Some resonances may not be excited because of the zeros in the modulus spectrum and also resonances outside the region of interest may be excited as the spectrum is infinite in extent, although the spectrum level generally decreases as frequency increases and must eventually become insignificant.

(c) It would be difficult to preserve the pulse shape when applied through conventional vibration test equipment and hence if this necessitates analysis of the applied force pulse then the main advantage of single pulse excitation is lost.

For these reasons the rapid frequency sweep technique was investigated. This must not be confused with the quasi-steady state slow sweep technique mentioned in the introduction because in a transient test the concept of a steady state is not applicable and the analysis of equation (1) must be performed. The linear swept sinewave is the function,

$$F(t)=\sin(at^2+bt) \qquad 0<t<T \qquad \ldots (15)$$

where if f_1=the initial frequency
and f_2=the final frequency

$$b=2\pi f_1 \text{ and } a=\frac{\pi(f_2-f_1)}{T}$$

Thrall *et al.*[6] have demonstrated theoretically that the power spectrum of a swept sinewave defined by equation (15) exhibits the following properties:

(i) the spectrum is not flat but two peaks approximately $1{\cdot}4\times$ mean spectrum level in height occur at $f_1+1{\cdot}2\sqrt{\left(\frac{a}{2\pi}\right)}$ Hz and $f_2-1{\cdot}2\sqrt{\left(\frac{a}{2\pi}\right)}$ Hz.

(ii) the mean value of the spectrum$=\frac{\pi}{4a}$.

(iii) the amplitude of the ripple superimposed on the mean spectrum level is proportional to $\frac{1}{\sqrt{T}}$.

An all solid state frequency sweep oscillator has been developed[7] which enables extremely rapid linear frequency sweeps to be made with constant amplitude through any part of a 0—20 kHz frequency range, the initial and final frequencies being set manually on precalibrated potentiometers. A typical output voltage waveform is shown in Fig. 4. The modulus and phase spectra of a sweep from 100 Hz to 1 kHz in 2·5 sec., obtained by computer analysis are shown in Fig. 5. The high cut off rates at f_1 and f_2 are apparent, hence the swept sinewave is extremely suitable for transient excitation in structural testing,

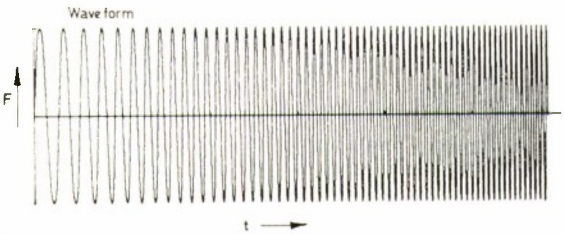

FIG. 4. A swept sinewave.

because of the high degree of frequency selectivity possible. The two peaks at the extremities of the sweep range are particularly evident in Fig. 5. The inequality in the heights of the peaks is due to the computational process being begun by the waveform exceeding a preset triggering level and hence a small part of the low frequency end of the spectrum is missing as it is contained in the part of the waveform whose amplitude is below the triggering level. The effect of the peaks is easily overcome in a frequency response test by extending the sweep range slightly outside the frequency range of interest. From (ii) and (iii) it can be seen that by the choice of a suitable sweep time the signal to noise ratio of the test measurements may be maximised and also the ripple may be minimised. It can be seen however from Fig. 5 that the nature of the phase spectrum of the swept sinewave is such that serious system phase measurement errors occur if the system response alone is analysed and hence the excitation and response time histories must be recorded and the division indicated in equation (1) carried out.

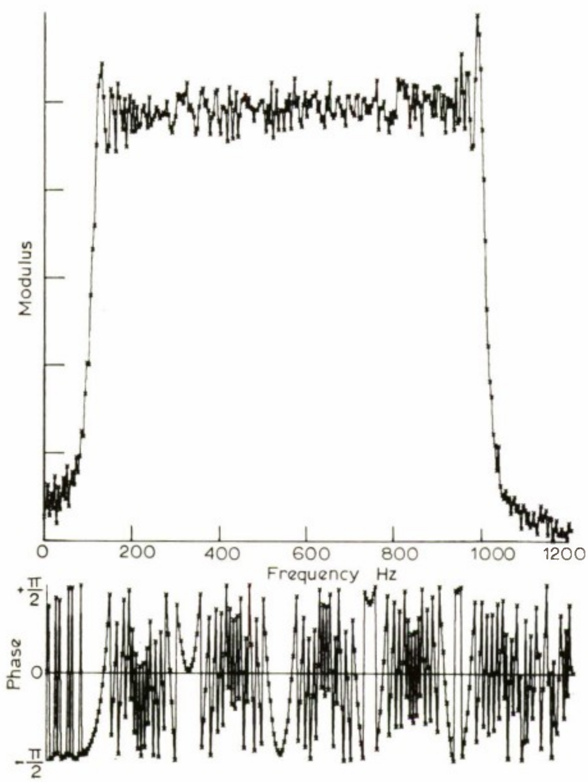

FIG. 5. Spectra of a swept sinewave $f_1 = 100$ Hz, $f_2 = 1$ KHz, T=2·5 sec.

Transient excitation sweep 50Hz to 1200Hz in 1·0 sec.

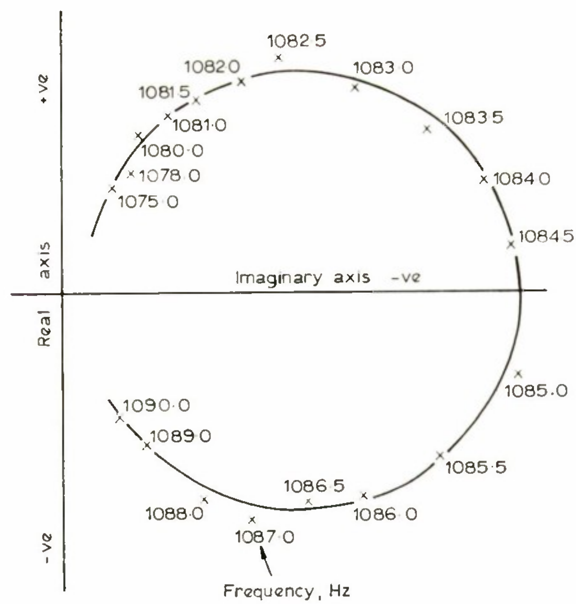

FIG. 6. Frequency response of 4th mode of the simply supported beam.

The frequency characteristics of the first four modes of a simply supported beam were investigated by the rapid frequency sweep technique. The swept sinewave was applied through a power amplifier to a coil on the beam as described previously and the response was measured from a strain gauge. The force and response were recorded, the former being obtained by recording the current through the coil. The frequency was swept from 50 Hz to 1200 Hz in 1 sec. and the test results, obtained by dividing the Fourier transform of the response by that of the excitation, are shown in Table II together with the results from steady state tests and the calculated values of f_n, Vector diagrams were obtained for each resonance by analysing 2 sec. of data for mode 1 and 4 sec. of data for modes 2, 3 and 4. A typical vector diagram is shown in Fig. 6 for the fourth mode.

Table II

The simply supported beam

Mode No.	f_n calculated	f_n measured steady state	f_n measured transient	% difference	ζ measured steady state	ζ measured transient	% difference
1	84·0	80·9	83·2	+2·85	·0763	·0691	−9·5
2	302	304·25	303·25	−0·33	·00074	·000761	+2·85
3	650	647·10	649·5	+0·37	·00185	·0020	+7·5
4	1075	1085	1085	0	·00198	·00185	−6·5

Conclusions

This study has shown that transient methods of measuring the frequency response of structures may be used advantageously now that the digital computer is established as a means of analysing transient data and the accuracy of steady state methods can be preserved.

The method of single pulse excitation is attractive since it has been established that if the system under test is lightly damped and the pulse is of short duration then, without incurring serious errors in the measurement of natural frequency and damping, only the system response need be analysed. Unfortunately the single pulse technique is not selective as little control can be exercised over the range of resonances excited. The rapid frequency sweep technique shows great promise for structural testing because of the control available over the spectral properties and frequency response functions may be measured accurately by division of the Fourier transforms of the system response and excitation time functions.

Further work is being carried out to investigate the effect of extraneous noise on the test data. The problem of resolving close natural frequencies and the effect of system non-linearity are also being studied.

Acknowledgement

The author wishes to thank the Ministry of Defence (Admiralty Engineering Laboratory) for their sponsorship of the unclassified contract under which this work was carried out.

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BIRTHDAY HONOURS, 1969

Mr. D. Malcolm, B.Sc., Superintendent of Scientific Personnel (N) has been honoured by Her Majesty the Queen in the 1969 Birthday List. We should like, on behalf of the Royal Naval Scientific Service to offer sincere congratulations on the award of the Imperial Service Order.

AN AUTOMATIC DATA LOGGING AND COMPUTING SYSTEM FOR THE HYDROGRAPHER

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Introduction

This paper is concerned with a logging and computing system that is being fitted in the Hydrographer's three new Oceanographic Survey Ships, H.M.S. *Hecla, Hecate* and *Hydra.* The system has been designed to read automatically the outputs from a large number of sensors, to do a certain amount of computation in a general purpose computer, and to present the results in forms suitable for immediate use on board and for later, more detailed, analysis at the Hydrographic Chart Office, Taunton.

Prior to the introduction of the new *Hecla* Class ships, the Hydrographer's surveys were concerned almost entirely with obtaining soundings which could be manually read from instruments and manually recorded fairly satisfactorily. The new ships, however, contain instruments for measuring gravity and magnetism as well as depth, and the number of men required to read and record all these data is very large. Further, to obtain useful results from the gravity meter it is necessary to know accurately the ship's speed relative to the ground. This can be determined from a knowledge of the ship's position at frequent and known times and requires that several instruments be carefully read simultaneously—a difficult requirement to meet manually.

For most surveys, the surveying ship steams at about 10 knots along a pattern of nominally straight lines until the whole area to be surveyed has been covered. At regular intervals, which may vary from one to 10 minutes, readings are taken from all the instruments relevant to the particular survey. This process can continue for two weeks or more, after which all the records obtained are sent to the Chart Office where they are corrected for errors, modified where necessary and then translated into a form suitable for analysis in a computer. With so many manual processes involved throughout the whole sequence, the number of clerical errors made is understandably large. Apart from this problem, the Hydrographer's greatly increased ocean-going fleet and the more comprehensive and detailed records obtained by each vessel would cause far more information to be fed into the Chart Office than could possibly be dealt with if the existing procedures were retained.

The conclusion was reached that if the full potential of the new ships was to be realised then an automatic method of recording the outputs from the sensing instruments was essential, together with a system for analysing the records as far as possible on board. Devices already existed which could fulfil part of this requirement but nothing could provide all the facilities needed by the Hydrographer. A specially designed system has now been made which will do this and it is this system which is described below.

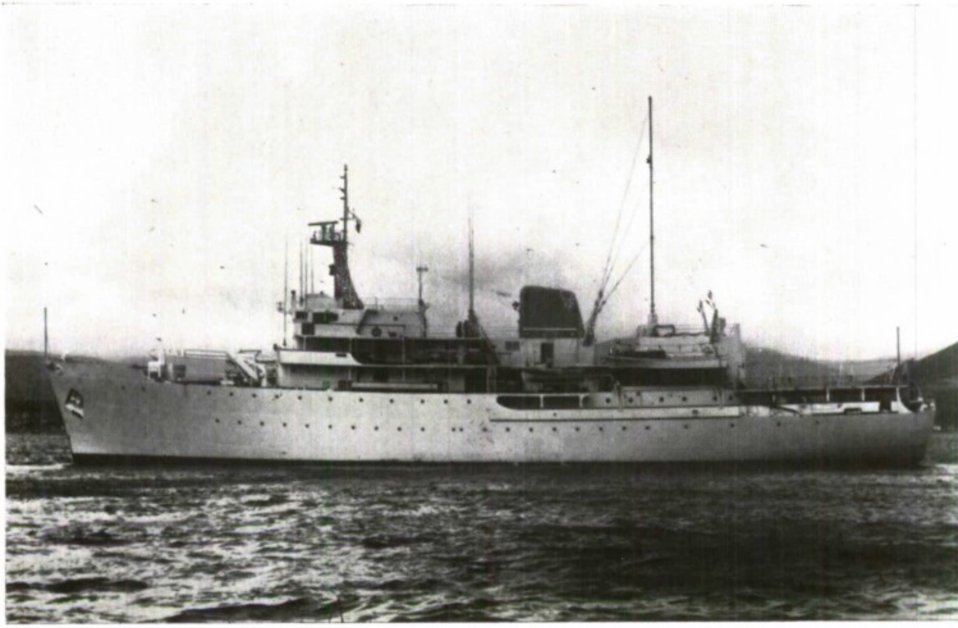

FIG. 1. H.M.S. Hecla

Hecla Class Ships (Fig. 1)

The ships were all launched in the first half of 1965. They are dual purpose, deep ocean survey ships, having a displacement of 2800 tons and a length of 260 feet. They are the first Royal Naval ships to be designed with combined oceanographic and hydrographic roles and to have no supplementary naval function. They are driven by diesel electric engines which can produce a maximum speed of 14 knots. Complete control is possible from the bridge (Fig. 2). This contains the most important sensors that need to be recorded, including the navigational aids and the depth recorders. Of the range of depth recorders in use the large precision depth recorder on the extreme left of the figure is for deep soundings and is the only one that is recorded automatically.

FIG. 2. Enclosed bridge.

All the remaining sensors of relevance have recorders situated in the ship's dry laboratory (Fig. 3). This laboratory is for scientific use as well as for routine surveying. It has provision for several cabinets of equipment and contains a wide range of power supplies. It is here that the bulk of the data logging equipment will be installed. The sensors that will be logged from the labora-

FIG. 3. Dry Laboratory.

tory are the magnetometer, gyro-compass, electromagnetic log, all the meteorological instruments and the gravity meter. The gravity meter itself is a very sensitive device which is housed near the gyro at the centre of the ship (Fig. 4). Readings from the gravimeter are at present taken from pen recorders located in the dry laboratory.

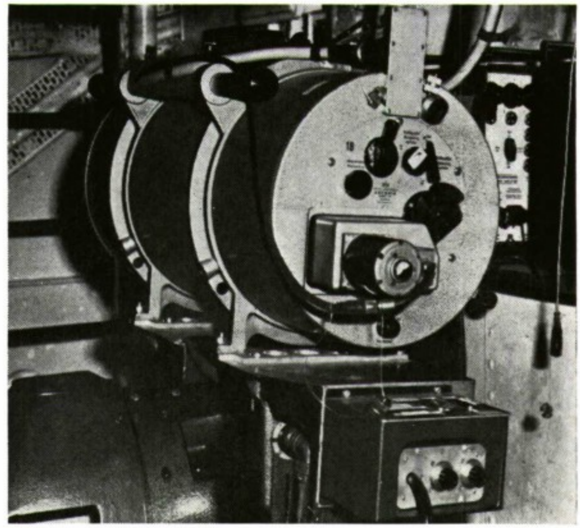

FIG. 4. Gravity meter.

The Logging and Computing System

Fig. 5 shows in simple terms the main elements of the system. It is centred round a general purpose computer. The outputs from all the sensors to be recorded are fed to specially designed interface units which convert the existing information into a form acceptable to the computer. The computer scans the sensors rapidly at regular intervals of time, and stores the complete set of data. In between scans, all the required computation is done in the computer and the useful results are fed to a variety of recorders.

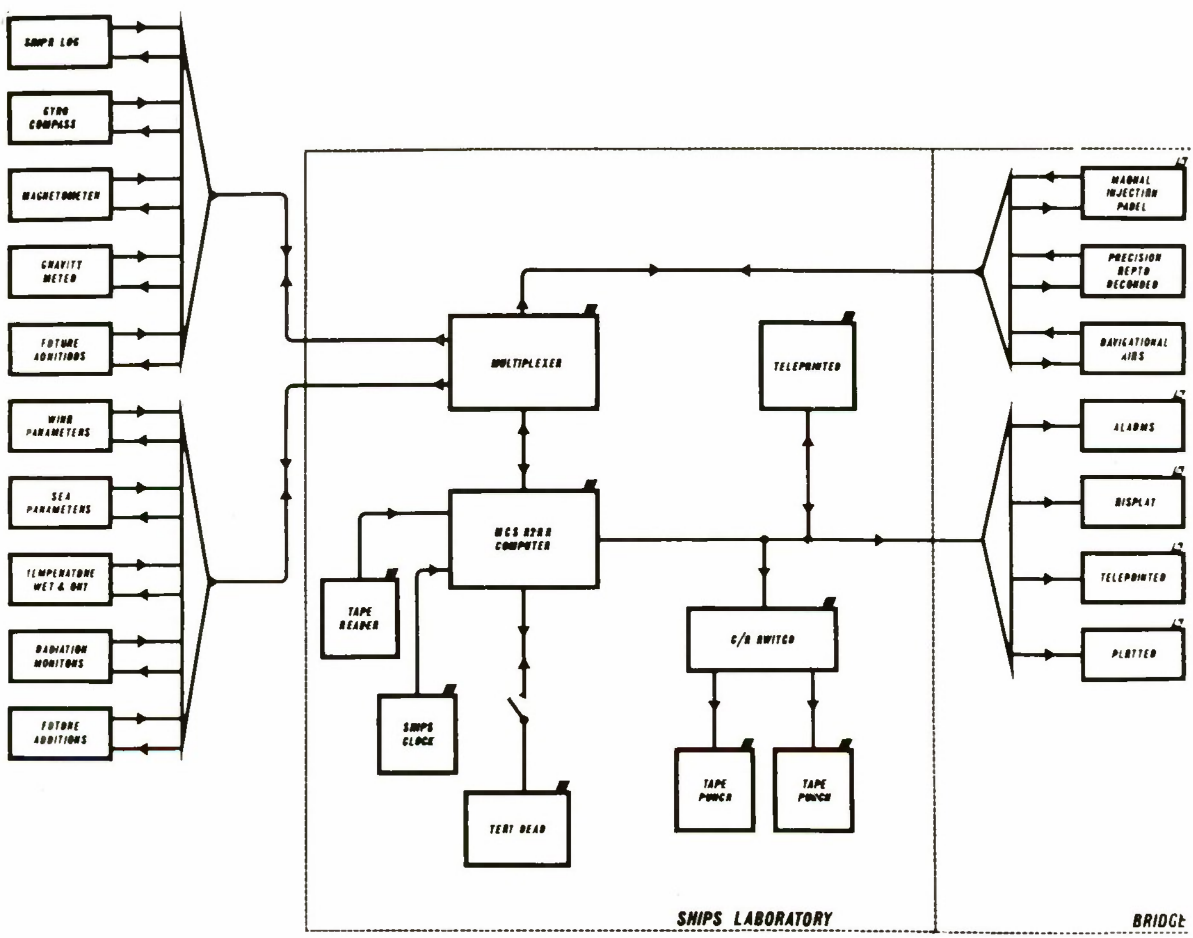

FIG. 5. Block Diagram

These comprise two teleprinters, one on the bridge and one in the dry laboratory, two paper tape punches, both in the laboratory, and an automatic plotter on the bridge. All the navigational information and the soundings are printed on the bridge teleprinter for immediate use. The complete set of data collected and the computed results are recorded on the teleprinter in the laboratory and on the paper tape punch for further analysis at the Chart Office. These recordings occur at intervals of time which may be set to between one and 10 minutes by the surveying officer.

Sensor	*No. of Digits Recorded*	*Value of Least Significant Digit*
Navigational Aids		
Decca		
Lambda	6	0·01 Lane
Hi-Fix		
Loran C	7	0·01μ sec.
Computations from Navaids		
Latitude	±7	0·001 min.
Longitude	±8	of arc
Speed	4	0·01 knot
Depth, Gravity, Magnetism		
Precision depth recorder	4	1 fathom
Gravity meter	4	0·1 milligal
Magnetometer	5	–
Heading and Speed		
Electro-magnetic Log	3	0·1 knot
Gyro-compass	3	1 degree
Meteorological Instruments		
Wind Speed	3	0·1 knot
Wind Direction	3	1 degree
Wet and Dry Thermometers	±3	0·1°C
Sea Thermometer		
Solarimeter	±4	–
Net Radiometer		
Barometer	4	1 millibar

Fig. 6. Details of Records

Fig. 6 lists all the sensors whose outputs are recorded, together with the number of digits recorded and the value of each digit. The system can have two navigational aids simultaneously on-line, and either of them may be any one of the four listed. Of the pair in use one acts as the master navaid and the position it indicates is used by the computer for all its computations. The second navaid of the pair is used as a check on the accuracy of the master. The outputs from the navaids are scanned by the computer at 10-second intervals and a value of position is derived by smoothing these readings over one minute. The computer then converts the smoothed position, which is in hyperbolic or circular units, to latitude and longitude. The ship's speed over the ground is computed from this information and used to correct the readings of gravity obtained from the gravity meter. The meteorological instruments are read at half-hour intervals. The recorded values of wind speed and wind direction are corrected in the computer for ship's speed and heading. The barometer differs from all the other sensors in that its readings are not recorded automatically by the logging system, but are manually injected from a panel situated on the bridge. This same panel is also used for injecting constants relating to the navigational aids and the precision depth recorder, and for certain checking functions.

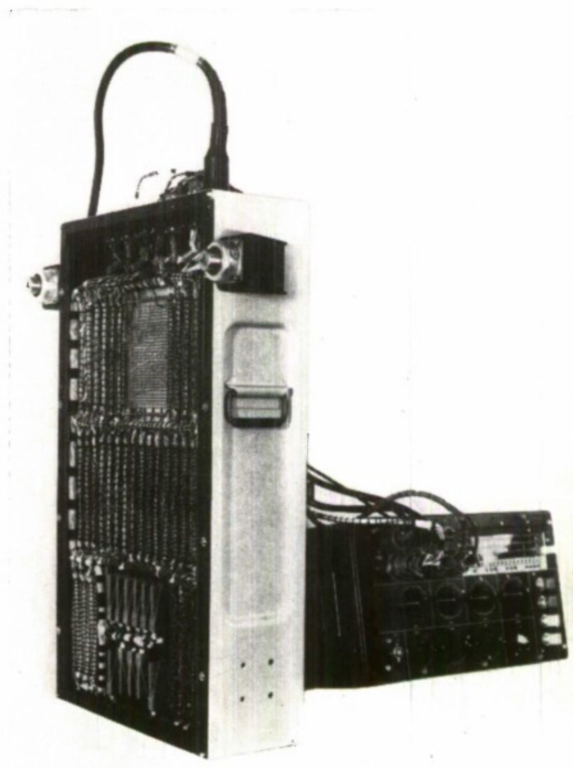

FIG. 7. 920B Central processor and test unit.

The computer is an Elliott 920B digital computer and is shown in Fig. 7 together with a special test unit. The main unit is 32 inches high. For the Hydrographer's application the computer has a capacity of 8000 words, although this can be increased at a later date if required. The com-

puter and its peripheral devices are controlled from the cabinet shown on the right of Fig. 8 which also includes all the power supplies. The computer operates in parallel mode and uses a word length of 18 bits. Instructions use a single address code and simple orders are obeyed in about 23 microseconds. Programmes may be held with four different levels of priority, a high priority programme always interrupting one of lower priority. Level 1, the programme of highest priority, deals with the basic timing of the system and with the transfer of information to and from the teleprinters and tape punches. Level 2 scans the sensors under the control of Level 1 and stores the information presented by the sensors. Level 3 does all the computations while Level 4 is concerned with simple testing of the system when none of the other levels is in use. When the computer is not involved with surveying, it can be used for off-line computations or programme development.

FIG. 8. Computer system in the dry laboratory.

Performance

The first complete system which was designed, built and programmed by Elliott Automation, was installed in H.M.S. *Hecla* in March 1968 (Figs. 8, 9 and 10). After the equipment had been connected to the ship's sensors and checks of the hardware made, the programming of the computer was completed and the system made ready for trials in June 1968. These lasted for five days and were aimed mainly at checking the operation and accuracy of the system. Apart from some minor shortcomings which were subsequently rectified, the results of the trials were very satisfactory. For the remainder of the 1968 surveying season the automatic system was used in parallel with the normal manual methods of surveying. This allowed comparisons in accuracy to be made between the two methods and an assessment made of the ease of operation and the reliability of the system under extended operational conditions. These have shown that the system operates satisfactorily for long periods with all sensors and can be operated with little difficulty. Two problems were observed, however, for which a watch needs to be maintained on the system and which were both expected in some degree. The first of these concerns the navigational aids. Only the fractional lanes are automatically read by the computer. The number of whole lanes has initially to be manually injected, the computer thereafter updating the whole-lane count each time the fractional lane crosses zero. In certain circumstances, this count can slip one whole lane relative to the number

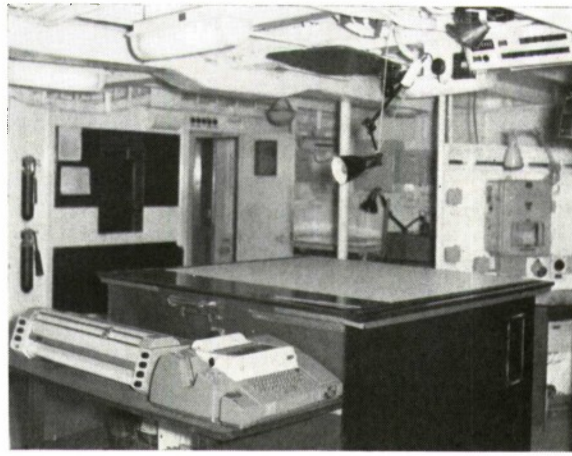

FIG. 9. Teleprinter. Plotter and manual injection panel

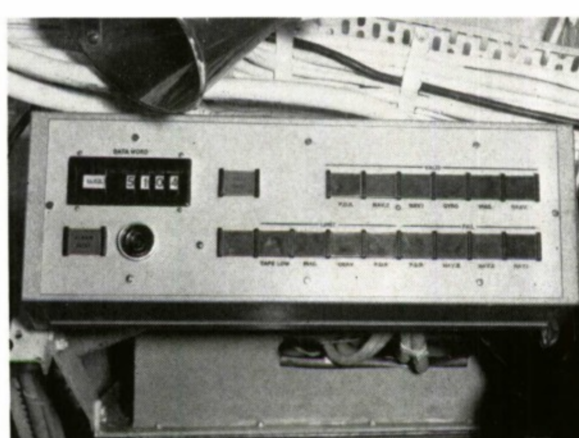

FIG. 10. Manual injection panel

indicated by the display on the navaid. In practice, this occurs only when the reception of the radio signals is poor. This error is easily detected and corrected. The second problem concerns the precision depth recorder. This is for use in water of up to several thousand fathoms in depth. In such deep water, the patterns of sonar echoes often contain considerable noise which a simple automatic system would find difficult to distinguish from echoes returned by the sea bed. For this reason, the digitiser for the depth recorder is preceded by an electronic gate which is initially set to the approximate depth of the sea bed and which only passes echoes received within a specified range either side of this depth. Once set, the gate automatically tracks the train of echoes that give the true depth. This works well unless a burst of noise happens to occur near the edge of the gate which will then centre itself round the noise. If the next genuine echo is further away from the centre of the gate than the previous echo, the system will lose track of the true depth. Again this is easily detected and corrected. The period of occurrence varies from several hours to a few minutes depending on the conditions of sea state and ship's heading. A more elaborate digitiser which would make the system operate in difficult conditions was not developed for the first system because of cost and time limitations.

It is difficult to draw any conclusions yet on the likely operational reliability of the system. It has worked continuously over periods of several weeks. On the other hand, faults have occurred more frequently at other times. However, for a first system which has been used experimentally as well as operationally throughout its period on board and which has been subjected to considerable artificial testing and a certain amount of modification, it has worked very well.

Current and Future Development

Work is currently in hand to make use of the computer to obtain more accurate navigational information by suitable computation. This is required so that accurate estimates of the ship's speed over the ground can be obtained for use in the calculation of gravity. Movement of the ship in an east-west direction appreciably affects the readings from the gravity meter and errors in the estimated ship's speed at present contribute significantly to the errors in the computation of free air anomaly of gravity. A second and predominating source of error is the cross-coupling error introduced into the indication gravity by imperfections in the stabilisation of the gravity meter. Means of correcting for this error are being studied.

Among other items that will be integrated with the system are the Omega and the satellite doppler navigational receivers both of which will shortly be fitted into the Hydrographer's Fleet.

Other Applications

The system that has been described is suited to the Hydrographer's needs. However, the approach that has been adopted is flexible and is applicable, with the same basic equipment, to a wide range of requirements. A similar system is already being built as an experimental tool for use on a fishing vessel to help with research into methods of improving the efficiency of trawling. Several sensors are common to the Hydrographer's, such as the *Decca* navigational receiver, electro-magnetic log and gyro-compass. Other sensors are different, such as one which measures the strain in warps carrying the fishing net, and these need special interface units. The central equipment and its general organisation, however, remain similar.

Conclusion

It should be noted that this system does not make any of the basic sensors operate more automatically than they did previously, but by automatically reading the sensor outputs, it allows surveys to be conducted more efficiently, accurately and in greater detail than is possible manually, and reduces the time needed for data processing both on board and at the Hydrographic Chart Office. It is too early to assess the full value and potential of the system but experience to date suggests that all its requirements will be met and that it will soon form an indispensable part of the Hydrographer's aids to surveying.

EXPOSURE TRIALS STATION, EASTNEY

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Exposure Trials Station
Central Dockyard Laboratory

Introduction

The Exposure Trials Station, Eastney, is an out-station of the Central Dockyard Laboratory, Portsmouth, providing facilities for the testing of paint and metallurgical samples on sea-water immersion and aerial sites. From this basic testing facility has grown a laboratory system which provides for both the physical testing of materials and a research programme into marine biology.

This article is intended to give a brief description of the growth of the Station and an outline of the various aspects of the work conducted there.

Origins

Historically the Station is descended from the Central Metallurgical Laboratory, Emsworth, which started the sea-water immersion trials for the Admiralty using a small raft in Emsworth Pool. In 1945 the trial facilities were extended by the addition of a larger, more seaworthy raft which was moored in deeper water near the mouth of Chichester Harbour. Expansion of the work led to the addition of new rafts in 1948 and 1953 and the construction of an aerial exposure site on Pilsey Island.

In December 1956, C.M.L. was closed and the responsibility for the metallurgical and exposure trials work was transferred to the Admiralty Chemical Department which was renamed the Central Dockyard Laboratory.

This transfer added another aerial exposure site at Horsea Island to those of C.M.L., the Horsea Island site having been opened in May 1953 for use by A.C.D. The wide scatter of the sites and the need to concentrate the work on C.D.L. led to the setting up of a new station on Eastney Point and the rafts being resited in the main channel of Langstone Harbour.

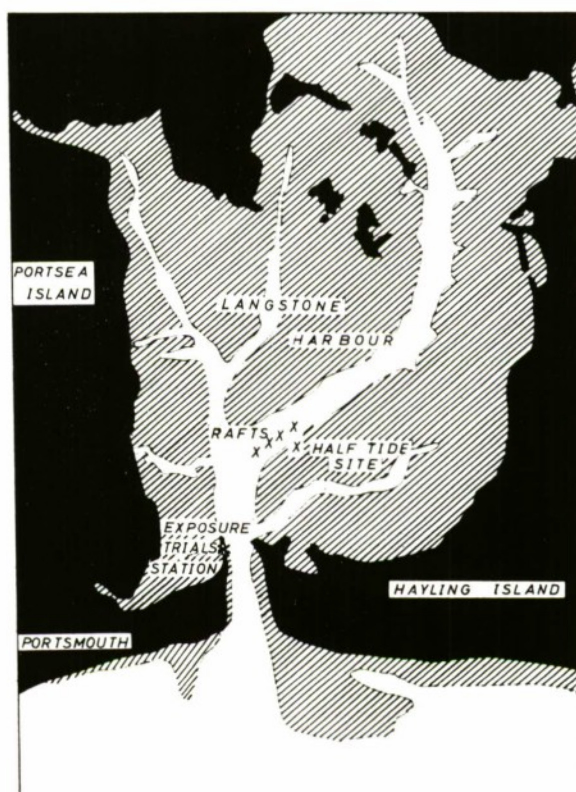


FIG. 1. Langstone Harbour, showing exposure trials station, rafts and half tide site.

In 1959 the oldest raft, of wood construction, was replaced by a new one made of steel and a fourth raft was added in 1963. The latter was originally designed to carry "thin planks" for skin frictional resistance measurements to be carried out at A.E.W. When these studies were dropped the raft was converted to carry the normal exposure frames. Three small boats are maintained for servicing the rafts and carrying out scientific studies.

The Eastney Site and its Development

The choice of Eastney Point for the Exposure Trials Station was made after extensive investigation had been made into alternative sites. Portsmouth Harbour had much to recommend it from an administrative point of view, but no moorings were available near the harbour mouth where three 60 ft. × 30 ft. rafts could swing freely at single moorings. The northern end of the harbour was unsuitable because of the amount of freshwater outflow and/or pollution. In consequence the area had a fouling community very different from that found in the normal highly saline coastal sea-water.

During the investigations it was shown that Langstone Harbour had a high salinity (average 33·6‰), very little freshwater outflow and the fouling community was similar to that of coastal waters. A suitable area of Admiralty land was available on the point, clear of the City of Portsmouth Sewerage Works, and with ready access to the sea on either side; until a few years earlier this plot had been in use as a market garden. Official approval to use the site was obtained and a small 6 ft. × 6 ft. gardener's hut was occupied on the 1st August, 1957. In a short space of time better accommodation followed in the shape of the old temporary photographic studio building from C.M.L., this was erected and modified internally to provide a small office, laboratory and paint trial preparation room. A single storey brick building was added to the site in 1960 providing a larger laboratory and offices and this was extended in 1961, to provide more laboratory space and storage room. Also in 1961, a small sea-water pump house and an inflammable store were added.

1. 1957 Original temporary building
2. 1960 Single storey brick building
3. 1961 Extension and storage space
4. 1961 Pump house
5. 1961 Inflammable Store
6. 1965 Two storey office/laboratory block
7. 1965 Electrical switchboard and toilet block
2. 1968/1969 Upper storey laboratories and photographic dark room
8. 1968 Extension of compound area
9. 1969 New laboratory block
10. 1969 New compressor house and store block.

The provision of a constant supply of once-through sea-water was a major step forward, tests having shown that re-circulated sea-water when used in biological and metallurgical research can give very different results to those obtained using once-through sea-water. To achieve a good flow of sea-water free from toxic substances it is essential to have a short path from source to laboratory using inert materials throughout the system. To maintain good quality sea-water it should be passed as directly as possible to the experimental rigs. If it has to be pumped over long distances there is a further disadvantage in that the number and size of the pumps has to be greatly increased.

The unique facilities of the Station began to be recognised in the early 1960's and more and more use was made of the Station by members of the staff of the main C.D.L. laboratories. This led to a need to increase the laboratory and general accommodation; a two storied laboratory and office building together with a single storied transformer house and toilets were built in 1965. A large darkroom and extra laboratories were added

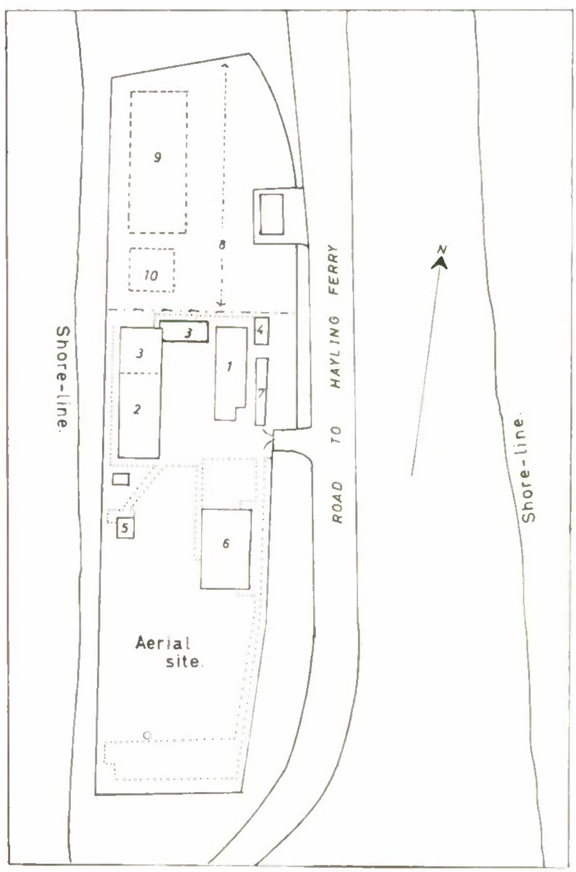


FIG. 2. Plan of the exposure trials station.

in 1968/69 by the erection of a second floor over the original brick laboratory and its extension. The perimeter fence has been extended to the North and another half acre of land enclosed. A laboratory block and a compressor house, grit blasting room, battery charging room and store are to be built during the summer of 1969.

Much of the growth of the Station has stemmed from the once-through sea-water system and the demand for sea water has been considerably increased over the last few years. In order to satisfy this demand a new pump house is being built with pumps capable of supplying 60,000 gallons of sea-water per hour.

As a result of this expansion the Exposure Trials Station will have chemical, paint, metallurgical, testing and biological laboratories with darkroom, workshop and office accommodation to serve them, providing facilities for marine biological studies and the physical testing of materials.

Exposure facilities—The rafts

There are four rafts, of steel construction, three capable of taking 50 exposure frames each and the fourth only 24 frames. The total capacity therefore is 174 frames, each of which can carry fifteen 10 in. by 15 in. panels, or 2,610 panels in all. Each raft is fitted with a small hut which serves as a shelter, store and as a rough laboratory; they are used to house the control system for cathodic protection trials and continuous temperature recorders.

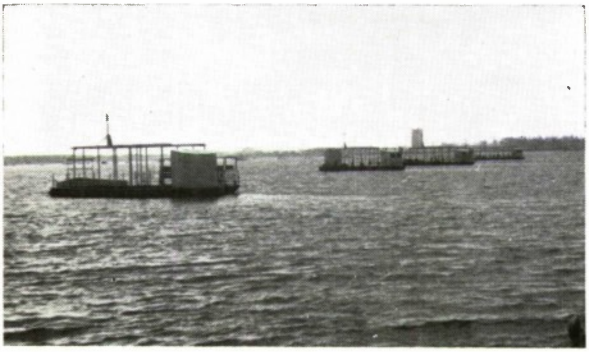


FIG. 3. The four rafts anchored in Langstone Harbour..

The frames are raised and lowered by means of a block and tackle attached to the overhead pulley system; the transportation of personnel and materials is carried out by three boats. They are an essential part of the trials system and are also used for collecting plankton and other marine organisms for use in the laboratories. On occasion trials of equipment under way are carried out by the boats and the fastest is used to sample water at speed for analytical purposes.

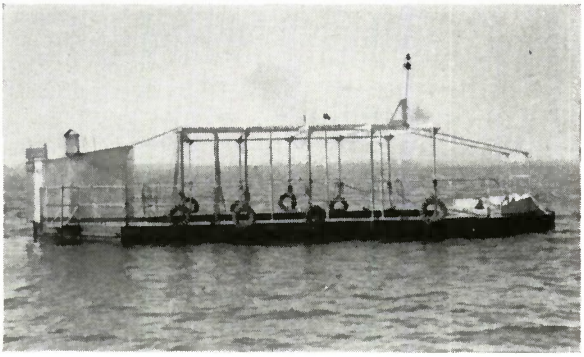


FIG. 4. Beam view of one of the rafts.

Half tide site

A series of twelve 60 ft. long frames are situated on the Sinah Sands to the east of the rafts. These frames are alternatively covered by the tide and exposed to the air giving rise to a very corrosive condition. Above the half tide frames are racks which reproduce the above-waterline exposure.

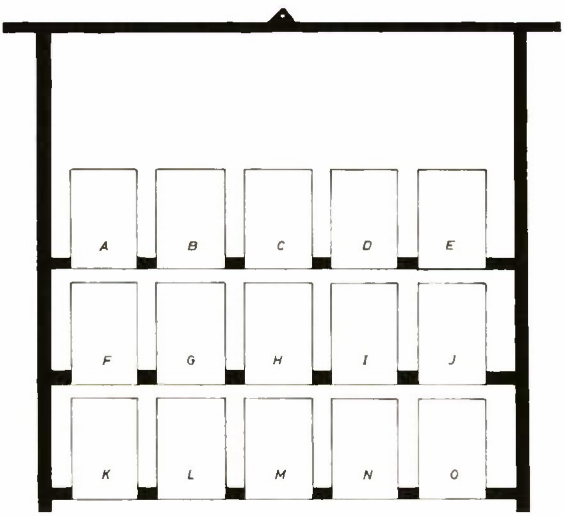
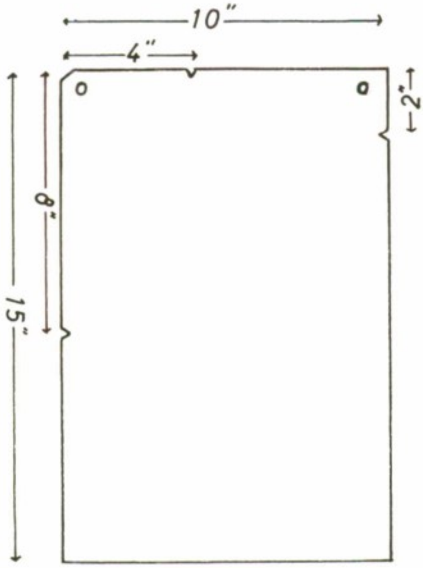


FIG. 5. Drawing of a frame showing the panel positions.

Aerial site

The southern part of the compound is used as aerial exposure site providing a marine atmosphere for the testing of weatherwork paints and other materials. Twelve 45° racks set in concrete provide for the exposure of panels facing S.W. by S. together with two series of racks in a vertical position.

Routine measurements are taken on the rafts and aerial site. Continuous sea and air temperatures, percentage of oxygen saturation of sea-water, salinity and the light penetration by means



Panel number 482.

FIG. 6. Numbering system used for panels.

of a Secchi disc at the former and the number of hours of sunshine, the amount of ultra-violet radiation on the area, maximum and minimum temperatures and the time that the panels are covered with a water film at the latter.

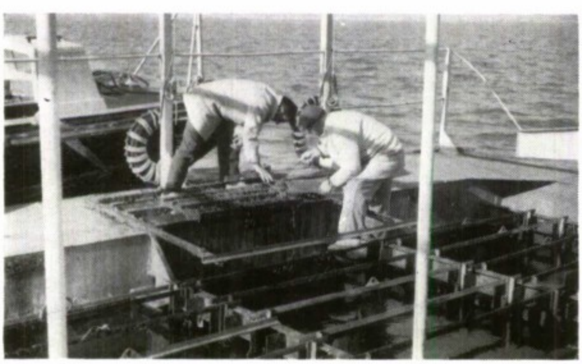


FIG. 7. Working on one of the frames.

Exposure testing—Preparation of samples

Grit blasted standard mild steel panels 15 in. by 10 in. by $\frac{1}{8}$ in. are used in the majority of programmes, they are painted in accordance with the relevant programme requirements. Control panels are prepared using one of the standard systems below:—

(a) five coats of Formulation 655 Protective Paint and two coats of 161P Antifouling Paint; or

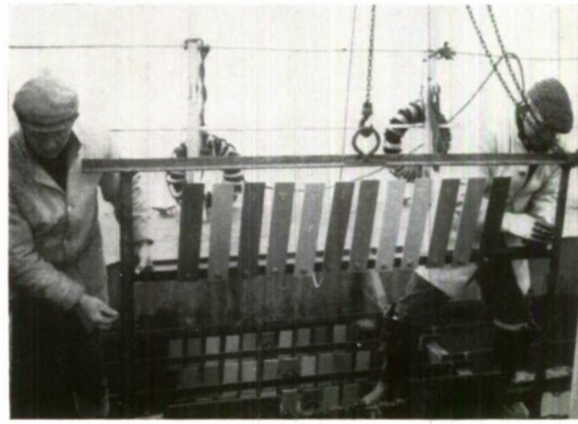


FIG. 8. Lowering a frame into position.

(b) three coats of Coal-Tar Epoxy Protective paint and two coats of 161P Antifouling Paint.

Wet and dry weights of each coat of paint are recorded except that wet weights cannot be measured accurately in paints with a high volatile content.

Other types of panel are used such as aluminium, glass reinforced plastic and wood according to requirement.

FIG. 9. The half tide site.

Marine testing

Raft panels are inspected and assessed at monthly intervals for marine fouling and for deterioration of the paint system.

The fouling season usually occurs from the end of March to the end of October, but can vary from one season to another; in both 1959 and 1968 *Tubularia larynx* settled as late as early December.

Programmes are immersed at all times of the year, except where there are special reasons for immersion at a specific time and the panels are assessed monthly unless adverse weather conditions prevent it.

FIG. 10. Part of the aerial site showing eight of the racks.

Fouling

The recording of fouling is based on a simple numerical system which is designed to show the fouling condition of the paint schemes under test. Under this system fouling organisms are divided into five groups, designated "a" to "e", which show increasing sensitivity to copper. Thus in group "a" are listed the slime organisms that show greatest resistance to the common antifouling poisons, followed by the slightly less resistant organisms of group "b". The appearance of the barnacles and brown alga *Ectocarpus* of group "c" on test panels is indicative of the loss of antifouling action.

The settlement of the organisms in groups "d" and "e" show the further decrease in toxicity of the paint to the point where it is to all intents non-toxic. A table of the species included in groups "a" to "e" is given on the facing page.

FIG. 11. Frames in position on one of the rafts.

Assessment in group "a" is based on a 0 - 4 system according to the heaviness and extent of the slime film. For groups "b" to "e" the 0 - 4 ratings are dependent upon the number of individuals present as shown in the following table:—

0 = up to 5 individuals	
1 = 5 - 10	,,
2 = 11 - 25	,,
3 = 26 - 50	,,
4 = 50 plus	,,

The assessment for each face of the panel is arrived at by taking the highest figure in group "b", "c", "d" or "e" which results from the product of the group rating times the sensitivity factor. The average assessment is the total of the highest figures for the front and back faces of the panel divided by two.

Paint condition

At each monthly assessment the amount of chalking, cracking, blistering, flaking and rusting is recorded. Chalking and cracking are assessed on an arbitrary 0 - 4 scale because of the difficulty of applying an accurate quantitative assessment.

Blistering, flaking and rusting are more readily recorded on a percentage basis and each of these conditions is given a weighting, blistering x 1, flaking of the antifouling paint x 1, flaking of the anti-corrosive paint x 2, and rusting x 10. The size of blisters is also recorded as fine, medium or large.

When a paint trial is terminated the panels are cleaned to remove fouling and then assessed in the laboratory for paint condition.

Heavy fouling of the panel in anti-corrosive paint trials precludes assessment in the field of the anti-corrosive paint film despite the fact that a coat of antifouling paint is usually applied. The reason for this is that the anti-corrosive paints give protection for longer periods than anti-fouling paints. In these cases it is usual to inspect one of the trial panels in the laboratory after the appropriate time of exposure and, if necessary, the other panel can be left to continue the test.

The assessment of fouling and paint condition provides data on the interval of time for which the systems are effective. Anti-fouling paints are deemed to have failed when the monthly average assessment is 3·0 or more for two successive months followed by progressive fouling of the paint. The appearance of rust marks the end of the effectiveness of the anti-corrosive paint for steel substrates.

Metallurgical exposure testing

In addition to the testing of paints by sea-water immersion a comprehensive range of metals and alloys have undergone marine exposure; these

FOULING
Sensitivity Groups

Sensitivity Group	*Sensitivity Factor*	*Plants*		*Animals*	
"a"	×0	Slime Organisms			
		Bacteria			
		Diatoms	*Amphiprora* *Navicula* *Achnanthes*	None	
"b"	×2	Green Alga	*Enteromorpha*	Hydroid	*Tubularia*
"c"	×3	Brown Alga	*Ectocarpus*	Barnacles	*Balanus spp* *Elminius*
"d"	×4	None		Hydroids	*Obelia* *Plumularia*
"e"	×5	Green Algae	*Cladophora* *Ulva*	Sponges	*Leucosolenia* *Sycon*
		Brown Algae	*Laminaria* *Punctaria* *Cutleria*	Tubeworms	*Pomatoceros* *Hydroides* *Serpula*
		Red Algae	*Ceramium* *Polysiphonia*	Mussels	*Mytilius*
				Saddle Oyster	*Anomia*
				Polyzoa	*Bugula*
				Sea Squirts	*Ascidia* *Ciona* *Botryllus*

Chalking and Cracking x 0	*Blistering x 1*	*Flaking: Anti-fouling x 1*	*Flaking: Anti-corrosive x 2*	*Rusting x 10*
0 None 1 Trace 2 Moderate 3 Severe 4 Very severe	← Percentage of painted surface areas →			
	Fine — up to 2 mm diameter Medium — 2 to 5 mm Large — greater than 5 mm			

include stainless steels, aluminium alloys, copper alloys and the more unusual materials such as indium and titanium. This testing provides data for engineering design and is collated and issued as Ad. Guide 106, a publication which is also issued by H.M.S.O. in an edited form. One such material recently developed by C.D.L. is an alloy of silicon aluminium bronze.

Metallurgical samples are usually totally immersed but some trials are carried out using a waterline immersion. The material under test is exposed on its own, in galvanic couples with other materials, or in rigs to induce crevice corrosion.

Cathodic protection

There are two aspects of the work carried out on cathodic protection, the first being to establish the particular alloy of zinc, aluminium, platinised titanium, etc., that is best suited for use on outer-bottom protection or for the protection of inlet

tubes and other hull inlets and fittings. The second is to find suitable paints to resist the alkali generated at the cathode i.e. the ship's hull. Finally, the paint systems are raft tested under cathodic protection to see that they present no further problems such as poor adhesion of the anti-fouling to the anti-corrosive coats or failure due to stripping of the complete system.

(A more detailed article on this subject appears in the following article.)

Laboratory work—Biology

Research into marine fouling is undertaken at the Station; since barnacles are the major fouling organisms a large amount of the research is carried out on these species. The aim is to find better methods of fouling control.

Toxicity tests are carried out on late stage barnacle larvae to evaluate candidate toxins, with research into the biological processes leading up to settlement, metamorphosis and growth in order to develop the means of upsetting the life cycle and thereby effect better control of these and other organisms.

The present studies centre on the role of hormones in the control of barnacle larvae through all stages of its development from the free-swimming larva to the settling stage and young adult. This is a very attractive avenue of anti-fouling research since hormones in an animal exert very significant physiological effects in minute quantities. Work is continuing along a promising line which has indicated the existence and possible mechanism of a hormone system controlling breeding in the adults. A similar mechanism has been found in the larvae which would appear to control moulting and metamorphosis.

Metallurgy

The use of once through sea-water has provided an improved facility for the metallurgical work carried out. In consequence this work has expanded rapidly and has led to certain advances in the programme. High strain low cycle corrosion fatigue testing has been used to provide design data for sea-water pipe systems in deep diving submarines. The best materials have been found to be wrought cupronickel and various copper alloy castings. The latter materials are also associated with the programme for the development of high strength alloys.

The extensive use of copper based alloys in vital or sensitive fittings has led to a study of stress corrosion of these materials under conditions of fresh sea-water flow.

Impingement attack is conventionally defined as accelerated corrosion due to the continual removal of protective corrosion product films by turbulent water flow and has been responsible for more Naval heat exchanger failures than any other form of corrosion. An electrochemical study of the mechanism of this type of corrosion on model tube ends using once-through sea-water has cast doubt on conventional theories; further investigations to confirm the electrochemical results are being carried out in current long term tests.

Conclusion

The fight against marine corrosion and fouling is an extremely important one especially in relation to the choice of materials for use on ships or equipment to be used in the sea. Corrosion and fouling costs millions of pounds each year in maintenance, replacement and increased running costs, and affords an enormous field for research and development with good returns for break-throughs or improvements in anti-fouling and anti-corrosion techniques.

Through its parent body, the Central Dockyard Laboratory, the Exposure Trials Station and the work undertaken has expanded and developed immensely in the twelve years since the day it was established in a gardener's shed on Eastney Point. Its facilities are recognised as being unique and increasing requests for the Station to undertake work for commercial firms has underlined the fact that it answers a very real need in marine materials research. With the growing link with educational authorities and international organisations the Station has become widely known. Many R.N.S.S. establishments have requirements which have led them to make use of the facilities of the Station and each year there has been a marked increase in the service projects undertaken.

Acknowledgements

The author wishes to thank the Superintending Scientist, Dr. E. N. Dodd, the Officer i/c, Exposure Trials Station, Mr. D. R. Houghton, and Messrs. D. J. Tighe-Ford, J. C. Rowlands and L. Sawyer for advice and assistance in the preparation of this article.

LABORATORY AND FIELD TRIALS OF CATHODIC PROTECTION SYSTEMS

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Exposure Trials Station
Central Dockyard Laboratory

Introduction

Practical methods for preventing corrosion of metal structures have been required ever since the time that man started to produce implements and machines from these elements. Corrosion takes place through an electro-chemical process similar to that in a simple electric cell. Considering a metal immersed in the sea it is found that parts of the structure assume a different electrical potential to other parts of the surface forming in effect a short circuited cell. Positively charged ions leave the surface from an anodic area, resulting in corrosion of the surface at that point. The electric charge returns to the metal at the cathode, the cell being completed by conduction of the current through the metal itself. There are numerous reasons why areas of differing potential are found on the same metal surface. They may be due to variations in composition, differences in temperature, stresses due to cold working, variations in the dissolved oxygen concentration, presence of oxide films etc.

As corrosion is confined to anodic areas, it follows that if the structure to be protected is made the cathode, by connecting it to an external anode, that corrosion will cease. Cathodic protection can be achieved in two ways, either by using an impressed current or by means of sacrificial anodes.

The impressed current system uses a transformer/rectifier as an external source of D.C. electrical energy. The anodes may be permanent, semi-permanent or consumable. A permanent anode e.g. platinised titanium, is not corroded away. The corrosion products being the evolution of gases, primarily chlorine and oxygen. A semi-permanent anode such as a 2% silver lead alloy is corroded at a very slow rate and can last up to 10 years or more. The commonest form of consumable anode is scrap steel which corrodes fairly rapidly, about 20 lbs. per amp year being lost, and has to be repiaced at regular intervals.

Every metal when immersed in an electrolyte assumes a certain potential which is specific for the metal. The sacrificial or galvanic anode system is based on this phenomenon. Copper and its alloys has a potential of approximately $-{\cdot}25$v measured against a standard silver/silver chloride reference half-cell, steel $-0{\cdot}65$v, zinc $-1{\cdot}05$v and magnesium $-1{\cdot}60$v.

If a suitable metal with a more negative potential than the metal structure to be protected is chosen as the anode, the structure itself becomes the cathode and its potential moves towards a more negative value e.g. steel moves to a value of $-0{\cdot}85$v, and corrosion is prevented. With this system the anode is consumed and has to be replaced from time to time.

Facilities Available for Cathodic Protection Investigations

Experiments using both systems mentioned above have been carried out at the Exposure Trials Station, in the laboratory and on the rafts. The advantage of running laboratory tests at the Station is that use can be made of the once-through seawater system. It is imperative that the electrolyte, in this case seawater, should be continually replaced throughout the experiment. Seawater when stored or re-circulated is no longer strictly comparable to fresh seawater, due to loss of carbon dioxide, bacterial activity, etc. During the experiment hydroxyl ions are liberated at the cathode which increase in concentration unless flushed away by continual replacement of the water. The combination of these factors plus the build up of corrosion products in the electrolyte can lead to spurious results. A further advantage of carrying out investigations at E.T.S. is that rafts are available for conducting field trials of C.P. systems, before they are recommended for use on ships or other structures requiring protection. The use of a comparatively large structure enables the electrical conditions such as magnitude

of the current required and its distribution to be worked out. However, there are a number of problems which have to be faced in using the rafts. There is no electrical supply available and batteries have to be used for supplying the impressed current systems and they have to be changed frequently. More important, however, is that the current requirement varies with the speed of the water past the raft which varies with the tidal condition. This factor has to be taken into account when conducting the experiment and extrapolating results for specific applications.

Cathodic Protection Investigations

The investigations carried out are of two types.

(i) Investigations into materials used in C.P. systems.

(ii) Investigations of the effects of C.P. on paints for use on cathodically protected structures.

Investigations into Materials Used in C.P. Systems

These investigations have been mainly confined to finding better materials for anodes. Zinc or magnesium sacrificial anodes have been used for many years. Theoretically aluminium is better than either of them, having a better electrical output in amp/hr/lb. Its thermodynamic solution potential lies between that of zinc and magnesium, yielding a better driving potential than zinc but not suffering from the over protection problems of magnesium. Unfortunately, in practice, due to the oxide film formed, the solution potential is more positive than zinc and because of uneven corrosion, with subsequent loss of unused material, its electrical output per lb. is greatly reduced. Alloying with various other materials, mainly tin, zinc and mercury, improves the efficiency of aluminium and a number of commercially available alloys have been investigated, both in the laboratory and on the rafts.

One of the mercury containing alloys was found to be the most promising. Some of the aluminium-zinc-tin alloys showed similar promise but their efficiency was affected by the lower temperatures during the winter.

Zinc is in common use in many cathodic protection systems as a reference electrode but doubt has arisen concerning its stability and the effect of water movement on its potential. These problems have been studied in the laboratory and in addition measurements were taken of its potential, at varying speed, against a reference cell, when towed by one of the Stations' launches. It was found that the potential became more positive by as much as 30mv when subjected to quite slow speeds.

Investigations into the Effects of C.P. on Paints

As mentioned above, hydroxyl ions are produced at the cathode of a C.P. system. These ions can seriously damage paints applied to the structure. Those containing relatively large quantities of saponifiable material e.g. linseed oil, are readily attacked. The paint blisters badly, cracking occurs leading to loss of adhesion and flaking. It is therefore necessary to formulate paints capable of withstanding alkali attack. Promising compositions after laboratory tests are exposed on the rafts at several potentials some of which are greater than those to which the paint will be subjected in practice. Coal tar epoxy paints have been shown to be capable of standing up to these conditions.

In the region of the anode more negative potentials are experienced than elsewhere on the structure and it is general practice to surround the anode with a shield capable of withstanding the high hydroxyl ion concentration associated with these high negative potentials. Several materials have been used including neoprene rubbers, and rigid P.V.C. etc., but they are difficult to fix in place. A frigate doing high speed turns and other such manoeuvres imposes a large mechanical strain on these shields. In some cases they have been torn away with subsequent loss of the anode. It would be preferable if the shields could be dispensed with by using high duty paints. Both coal tar epoxy and solventless epoxy paints have shown promise, in preliminary trials, for this purpose. Solventless epoxy paints have been tested at values more negative than $-2{\cdot}0$v with reference to a silver/silver chloride half-cell. By adopting these paints the conventional shields can be greatly reduced in size.

Collaborative Work

Under the auspices of the Permanent International Committee for Research into the Preservation of Materials in the Marine Environment, a number of shop primers/anticorrosive systems are being evaluated in Langstone Harbour and several European and N. American Stations. A range of materials and systems have been included and it is hoped that much will be learned from comparison of the results.

The greater part of the work mentioned above has been carried out in conjunction with the main C.D.L. laboratory. It does, however, illustrate the importance of both the laboratory and field testing facilities of the Exposure Trials Station for cathodic protection studies.

Acknowledgements

The work on commercially available aluminium anodes was carried out by Dr. R. Holland who is now stationed at the Admiralty Materials Laboratory, Holton Heath.

THE INTEGRATED GLOBAL OCEAN STATION SYSTEM (IGOSS)

Lieut. Cdr. D. P. D. Scott, M.B.E., R.N.
Hydrographic Department

In December 1968, during its 23rd Session, the United Nations General Assembly adopted four resolutions, all relating to the exploration and exploitation of the oceans and therefore of vital importance to all whose work is connected in one way or another with the sea.

Resolution 2467A forms a permanent U.N. Committee on the Peaceful Uses of the Sea-Bed and the Ocean Floor beyond the Limits of National Jurisdiction* and lays down Terms of Reference for this Committee;

2467B deals with pollution of the oceans and other hazardous and harmful effects that might be caused by exploration and exploitation of the Sea-Bed and Ocean Floor;

2467C calls for a study on the question of establishing international machinery for the promotion of the exploration and exploitation of the resources of the area; and 2467D, after welcoming the United States proposal for an International Decade of Ocean Exploration (IDOE), invites Member States to formulate proposals for national and international programmes and requests UNESCO to see that its Intergovernmental Oceanographic Commission (IOC) intensifies its activities in the scientific field, in particular with regard to co-ordinating the scientific aspects of a long-term and expanded programme of world-wide exploration of the oceans and their resources.

From all this and much else that has been developing in the last year or two, it will be seen that research, exploration and exploitation of the oceans are bound to expand enormously during the 1970's. Public opinion in the United States has been fed with the idea of the vast potential of the oceans, to a much greater extent than in Europe, and, with the likely slowing down of the "space race" once men have been landed on the moon, it is certain that there will be growing insistence, under the leadership of men like Senator Claiborne Pell, for a transfer of large funds to a field in which the returns will be incomparably greater.

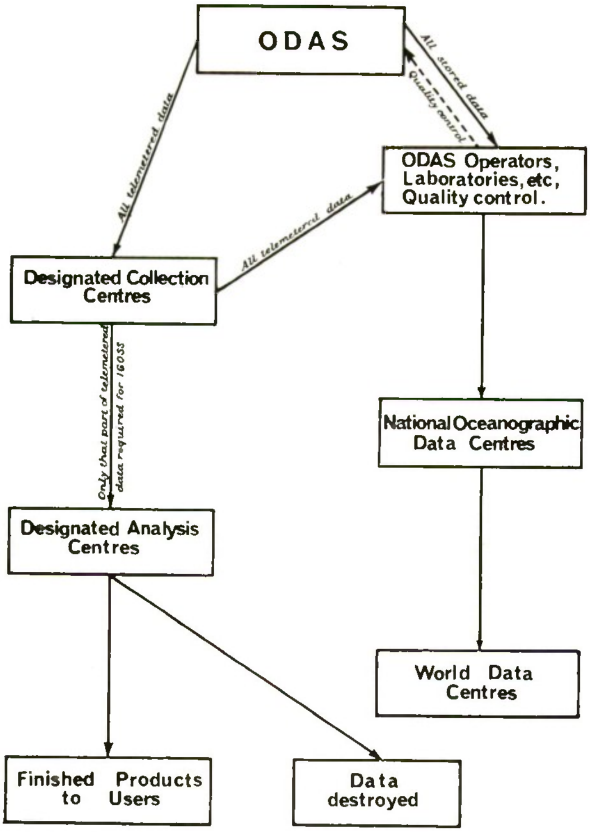
As part of this development, the Intergovernmental Oceanographic Commission are developing their IGOSS—Integrated Global Ocean Station System which envisages a network of stations over the oceans of the world, occupied by platforms, ocean weather ships, automatic buoys and so on, known collectively as Ocean Data Acquisition Systems (ODAS).

The data collected by these ODAS will be telemetered or transmitted to Designated Collection Centres where "synoptic" data from the upper layers is extracted and passed to Designated Analysis Centres for use in the preparation of charts and forecasts of the ocean environment.

IGOSS is complementary to and is being planned in collaboration with the World Weather Watch (WWW) of the World Meteorological Organization (WMO) and its research component, the Global Atmospheric Research Project (GARP), in order to avoid costly duplication of systems,

* This permanent Committee replaces the former Ad Hoc Committee of the same name which was established by the General Assembly by resolution 2340 (XXII), in December 1967.

wherever possible for instance, much of the IGOSS data will be transmitted initially over the WWW Global Telecommunications System (GTS).



IGOSS—Data Flow Diagram

The objectives of IGOSS are stated to be

(a) To collect ocean data from all parts of the world's oceans and transmit these data, in short time, to designated communications and analysis centres;

(b) To provide Member States with global synoptic oceanographic data, analyses (products), predictions and advisories, in short time;

(c) To give impetus and support to research into ocean processes and to incorporate applicable research results in the expanding IGOSS programme;

(d) To assist in increasing the safety and efficiency of maritime activities through its services.

Development of the system is being undertaken in two phases. During Phase I, it is intended to locate and co-ordinate all existing data sources and generally use existing technology, whereas in Phase II, it is intended to employ advanced technology, such as satellites, moored telemetering buoys, etc. It is however recognised that the development and deployment of such systems will be a gradual process which will start in a small way during Phase I and expand rapidly in the 1970's, during Phase II.

The Plan and Implementation Programme, Phase I, is now being given its final redraft and will be presented to the Intergovernmental Oceanographic Commission at its VIth Session in September 1969, for acceptance and approval to proceed with the project.

The benefits which it is hoped that a system such as IGOSS will confer on the world community are numerous and are seen to include:

(a) Navigation: tides, tidal currents, ocean currents, waves, sea ice;

(b) Coastal Warnings: tides, storm surges, tsunamis, surf, swell, currents;

(c) Fisheries: temperature, salinity and density as functions of depth, bottom temperature, currents, sea state, ambient light in the photic zone, water mass boundaries, oxygen content, oxygen saturation layer, plankton populations and distribution, fish availability, pollution;

(d) Meteorology: thermal and heat budget parameters, variation and vertical movement of the thermocline, waves, air/sea interaction;

(e) Research: climatology, planetary fluid dynamics, thermodynamics, oceanography in general and related scientific investigations.

PROBABILITY, JUDGMENT AND MIND
3—The Place of Mind in Nature—2

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Religious Needs

In this section we shall see how a need for God manifests itself in various people. We shall examine the expressed opinions of a few individuals —D. H. Lawrence, Louis Pasteur, Professor Everett and Bertrand Russell—and in general we shall see that "The movement among those who believe in any kind of God has therefore been towards a God who, in William James' phrase 'does a wholesale, not a retail business'—whose care is the future of life, not of individual souls. Some, while retaining the name of God, mean by it only the historical creator of the universe, credited by, for example, Eddington with a mathematical mind but not, apparently, the interest in human souls of the Christian God. Others, again, claim direct awareness, without the aid of reason, of a wider consciousness in which their individuality is mysteriously merged". It is perhaps fair, and not without interest, to record that it has been claimed that the Catholic Church is the only Christian church to show increasing numbers of members.

D. H. Lawrence wrote of life and consciousness thus: "The one universal element in consciousness which is fundamental to life is the element of wonder. You cannot help feeling it in a bean as it starts to grow and pulls itself out of its jacket. You cannot help feeling it in the glisten of the nucleus of the amoeba. You recognise it, willy-nilly, in an ant busily tugging at a straw; in a rook, as it walks the frosty grass".

The viewpoint of the philosopher and humanist is expressed by Professor Everett of the University of California: "Man has not often been able to tolerate the feeling that he inhabits an alien world, whose laws do not make sense in the light of his intelligence, and in which the writ of his human values does not run. Faced with the prospect of such intellectual and moral loneliness, he has projected personality into the cosmic scheme. Here he has found a will, there a purpose; here a creative intelligence, and there a divine compassion. At one time, he has deified animals, or personified natural forces. At others he has created a superhuman pantheon, a single tyrannical world ruler, a subtle and satisfying Trinity in Units. Philosophers have postulated an Absolute of the same nature as Mind".

We have the views of Louis Pasteur, who was born a Roman Catholic and remained one throughout his life. At the age of sixty he was elected a member of the Academie Française; the welcoming speech on that ceremonial occasion was made, ironically, by that great and wise agnostic, Ennerst Renan. In his reply Pasteur explained that although an inescapable conclusion of thinking, the notion of infinity is incomprehensible to human reason—indeed more incomprehensible than all the miracles of religion: "I see everywhere in the world the inevitable expression of the concept of infinity. It establishes in the depths of our hearts a belief in the supernatural. The idea of God is nothing more than one form of the idea of infinity. So long as the mystery of the infinite weighs on the human mind, so long will temples be raised to the cult of the infinite, whether God be called Bramah, Allah, Jehovah or Jesus . . . The Greeks understood the mysterious power of the hidden side of things. They

bequeathed to us one of the most beautiful words in our language—the word enthusiasm—en theos—a god within. The grandeur of human actions is measured by the inspiration from which they spring. Happy is he who bears a god within—an ideal of beauty and who obeys it, an ideal of art, of science. All are lighted by reflection from the infinite ".

And lastly here are the words of Bertrand Russell, writing at the age of 89: " I must, before I die, find some means of saying the essential thing which is in me, which I have not yet said, a thing which is neither love nor hate nor pity nor scorn but the very breath of life, shining and coming from afar, which will link into human life the immensity, the frightening, wondrous and implacable forces of the un-human."

These quotations set the scene, so to speak, and we are returned to psycho-analysis and man's need for religion, or God, by the words of Dr. David Stafford-Clark taken from " Psychiatry Today ". In these we see answers to some of Sherrington's queries, concepts common to the religions of East and West, and emotion as a primal force (it is, after all, more equally distributed that rationality) in a manner consistent with our primal urge for *completion.*

" We have seen that the principles underlying all forms of psychotherapy which have insight as their aim, including psycho-analysis itself, rest upon a number of hypotheses which can be regarded as pretty well established. The first of these is that behaviour is prompted chiefly by emotional considerations, but that understanding is necessary to modify and control such behaviour and the emotions behind it. The second is that a very significant proportion of human emotion, together with the action to which it leads, is not accessible to personal introspection, being rooted in areas of the mind which are beneath the surface of consciousness. The third hypothesis is logically derived from the first two as well as being supported empirically by the result of experiment: it is that any process which makes available to individual consciousness the true significance of those emotional conflicts and tensions hitherto repressed will thereby produce a heightened awareness and with it an increased stability and emotional control. This in turn will lead not simply to improved health in its widest sense, but also to a more mature and developed personality.

From the religious standpoint there is nothing exceptionable in this—as far as it goes. But it remains evident that even after complete and successful analysis the subject has still no more than his own individual human resources upon which to rely. And in fact these are not always enough. Herein lies the fallacy at the heart of the philosophical and anti-religious claims of some ardent disciples of materialistic psychology.

Sometimes the conflicts of which the subject becomes aware remain insoluble to him. Thrown back upon himself he finds no comfort and no solace in this final attempt at self-sufficiency. This is the crisis in analysis, and within its own framework analysis has no answer. The patient, groping beyond himself for the final answer, cannot get it from the analyst, for the transference, even if it were sufficient, cannot be maintained for a lifetime. In one of his last essays, 'Analysis Terminable and Interminable' Freud is most explicit on this point.

Where then can a man turn? If full self-awareness and self-realisation are not by themselves enough, what is? As a psychiatrist I know of no answer to this question: as a man I can only say with all humility that I believe in God.

Freud and Marx had this in common, that they rejected belief in God while clinging implicitly to the system of ethics whose basis they had explicitly denied. Seen in this light it is not religious belief whose future is an illusion, but belief in science which seeks to deny its own ultimate source.

It seems to me a vital necessity, if psychiatry is to play its proper part in Society, that it should avoid making claims which it cannot fulfil. In particular it would do well to cease suggesting that it can replace moral standards by theoretical expediency, or provide its own basis for human ethics and values. It can answer a number of questions about the way in which things happen; it cannot begin by itself to answer a single question as to why man is so constructed that they should happen in this way.

Freud himself, for all his passionate and sincere renunciation of religious belief and of the religious basis for ethical behaviour, nonetheless acted in his own life as though loving one's neighbour as oneself was indeed the key to happiness. He devoted himself tirelessly and often without regard to self-interest to the discovery of truth as he saw it, and to the application of his discoveries to the relief of suffering. It is not surprising that he was persecuted; understandable that the advent of Nazism in Austria compelled him to take refuge in England. But for a man who prided himself on the materialistic and deterministic nature of his methods and discoveries it might perhaps seem to be surprising that he should continue to act, to paraphrase Rex Warner, as though the spiritual supports of love and morality were still guiding him. It might have seemed to him a final and supreme irony that his system of psychiatric procedure, rooted in his own view in deterministic materialism, should have been so uncompro-

misingly rejected by the disciples of political materialism in Communist societies."

We cannot enter into a discussion on the kind of religion best fitted to give the spiritual solace that man occasionally seems to need. It may be remarked, however, that there is a great difference between Eastern and Western philosophies. Eastern philosophies feature the submergence of the Self in one vast Awareness, whereas the Western philosophies emphasise the sanctity of the individual. All favour "right action" and "right thought", etc., but the latter may be said to be more extreme in their definition of "right". Psychologically speaking, a "balance" corresponding to the "middle path" of Buddhism seems desirable—we shall see the Christian reply to this stated by C. S. Lewis. Buddhism[18, 19] has no creed and leaves much to the individual judgement concerning what is good for spiritual progress. A Buddhist philosophy is more compatible with Pantheism than is a revealed religion. Kenneth Walker in "The Conscious Mind" writes: "The natural drift of mysticism in the direction of Pantheism renders the relationship between mysticism and Christianity, Judaism and Islam less harmonious than that existing between mysticism and Buddhism, a religion or philosophy which is entirely compatible with Pantheism".

In "The Conscious Mind," Walker makes a brief survey of mysticism, rejecting Western philosophies and opting for a monism that elevates all matter to mind. His conclusions are substantially the same as the three "suggestions" we advance as additions to Dr. Good's "technique" of probability. The unconscious, which we have associated with the mathematical and physical substratum and have sought to describe by Stafford Clark's analogy of a mountain range, would correspond to the all-embracing Self: we have already referred to this analogy in terms of E.S.P., we could extend this further to include mystical techniques and the contemplative prayer of Professor Hardy (and others). It is imagined that the Awareness of the all-embracing Self would be the type of experience described by Sherrington when discussing unconscious learning—the nearest (and, doubtless, completely inadequate) example that comes to mind is "joie-de-vivre". It is interesting to note that in outlining the case for a dualistic philosophy Dr. Walker refers to Professor Penfield of California, a great authority on the brain, who believes in dualism and quotes a demonstration analogous to the cases of the charging bull and the miserable scientist Weston, which were quoted in a previous paper.

The mystical philosophy which impresses Walker greatly involves a division of the mind into "centres of activity": a categorisation reminiscent of Jung's concept of the structure of the personality. The description given of a physical particle is not unlike the following one by Professor Capek: "A material particle thus loses its character of a substantial entity, existing *in* space and enduring *through* time; it becomes a local and often only a temporary modification of the spatio-temporal medium which we used to call aether and whose spurious continuity hides its pulsational character. Whitehead was guided by a correct insight, when he proposed to replace the traditional term 'aether' by 'aether of events' in order to convey more adequately the absence of its infinite divisibility and its processlike character." A. N. Whitehead believed that so far as sense-awareness is concerned there is a passage of mind which is distinguishable from the passage of nature though closely allied with it. He believed, "We may speculate, if we like, that this alliance of mind with the passage of nature arises from their both sharing in some ultimate character of passage which dominates all being."

The following extract, taken in its entirety from "A Short History of English Literature" by Gilbert Phelps[20] exhibits similar sentiments, at the same time conveying the difference between two attitudes to Pantheism, and explaining the nature of each. The extract is quoted in full because it includes, among other things, undertones of Buddhism with mention of "right feeling" and "right doing", etc.; and because references to instinct, feeling and the senses have relevance for later comments on Analytical Psychology.

". . . But though there were so many factors that *might* have made Wordsworth's absorption in nature escapist, there were others sufficiently powerful to offset them. Chief among these was the seriousness of his moral purpose. He was not concerned with the beauties of nature from a merely aesthetic point of view (as were so many later nature poets), but from the point of view of a whole way of life and a whole range of human values. He was being absolutely sincere when in his Prefaces he declared his beliefs that people living close to nature were morally in a more healthy condition than those living in towns. For Wordsworth nature was the greatest of all educating and civilizing agencies:

'One impulse from a vernal wood
May teach you more of man,
Of moral evil and of good,
Than all the sages can.'

In reading these lines one might well imagine an echo from Pope's assertion that 'the proper study of mankind is Man' and indeed it is quite likely that Wordsworth had them in mind. On this particular score he had no quarrel with Pope.

But it seemed to him that the Augustan poets and philosophers had not pushed their enquiries far enough, that they had not been *sufficiently* realistic. In his Prefaces Wordsworth speaks of himself as first and foremost a psychologist—but one who has learned more of the truth about human nature than the Augustans, with their restricted ideas and their lack of confidence in the resources of the creative imagination, could possibly have done. Wordsworth believed that his duty as a poet was to recall men to that 'filial bond' with nature which alone can produce right feeling and right doing, and alone can bring about a 'wise passiveness', a 'beast that watches and receives', and which can induce

'. . . That blessed mood
In which the burden of the mystery,
In which the heavy and the weary weight
Of all this unintelligible world
Is lightened . . .'

Wordsworth's relationship with nature was set forth in loving detail in the greatest autobiographical poems in the language and though there may have been 'regressive' elements in his attachment to 'Mother Nature' there were also moments of insight into the mysterious regions of instinct, feeling, and the senses that are among the most memorable in English literature. And again it is the poetry that carries the revelation, *not* the prose sense. This can be strikingly illustrated by placing side by side two passages surprisingly similar as far as their overt Pantheistic content is concerned. One is from Pope's 'An Essay on Man':

'All are but part of one stupendous whole,
Whose body Nature is, and God the soul;
That charged through all, and yet in all the same;
Great in the earth, as in the ethereal frame;
Warms in the sun, refreshes in the breeze,
Glows in the stars, and blossoms in the trees,
Lives through all life, extends through all extent,
Spreads undivided, operates unspent . . .'

Here the 'meaning' is abundantly clear—and yet at the same time it is, imaginatively speaking, meaningless, whereas the second passage, which is from Wordsworth's 'Lines composed a few miles above Tintern Abben, on revisiting the Banks of the Wye during a Tour, July, 1798', superbly renders what is completely lacking in the lines from Pope, a feeling of religious exaltation and wonder:

'. . . A sense sublime
Of something far more deeply interfused,
Whose dwelling is the light of setting suns,
And the round ocean, and the living air,
And the blue sky, and in the mind of man:
A motion and a spirit, that impels
All thinking things, all objects of all thought,
And rolls through all things'."

How appropriate this sounds against the background of modern particle physics and our discussion in general.

A note of warning, however, is introduced by C. S. Lewis, indicating the Christian attitude to Nature. He writes: "If you take Nature as a teacher she will teach you exactly the lessons you have already decided to learn; this is only another way of saying nature does not teach. The tendency to take her as a teacher is obviously very easily grafted on to the experience we call 'love of nature'. But it is only a graft. While we are actually subjected to them, the 'moods' and 'spirits' of nature point no morals. Overwhelmingly gaiety, insupportable grandeur, sombre desolation are flung at you. Make what you can of them, if you must make at all. The only imperative that nature utters is, "Look. Listen. Attend".

The fact that this imperative is so often misinterpreted and sets people making theologies and pantheologies and anti-theologies—all of which can be debunked—does not really touch the central experience itself. What nature-lovers—whether they are Wordsworthians or people with "dark gods in their blood"—get from nature is an iconography, a language of images. I do not mean simply visual images; it is the "moods" or "spirits" themselves—the powerful expositions of terror, gloom, jocundity, cruelty, lust, innocence, purity—that are the images. In them each man can clothe his own belief. We must learn our theology or philosophy elsewhere (not surprisingly, we often learn them from theologians and philosophers) . . . Of course the fact that a Christian can so use nature is not even the beginning of a proof that Christianity is true. Those suffering from Dark Gods can equally use her (I suppose) for their creed. That is precisely the point. Nature does not teach. A true philosophy may sometimes validate an experience of nature; an experience of nature cannot validate a philosophy. Nature will not verify any theological or metaphysical proposition (or not in the manner we are now considering), she will help to show what it means.

And not, on the Christian premises, by accident. The created glory may be expected to give us hints of the uncreated; for the one is derived from the other and in some fashion reflects it.

In some fashion. But not perhaps in so direct and simple a fashion as we might at first suppose . . . But we need not surrender the love of nature —chastened and limited as I have suggested—to the debunkers. Nature cannot satisfy the desires she arouses nor answer theological questions nor sanctify us. Our real journey to God involves constantly turning our backs on her; passing from the dawn-lit fields into some poky little church, or (it might be) going to work in an East End

parish. But the love of her has been a valuable and, for some people, an indispensable initiation ".

There are some features of C. S. Lewis's words which call for comment.

(a) There appears little doubt that Sherrington is right when he declares that man is part of nature: the poky little church and the East End parish are just alternative parts of nature. The area in which we seek action depends on individual preferences and environments. Some choose Religion, others Science, Art, Medicine, Law, etc. The important fact hidden in these paragraphs is that they journey to God and are lighted by Him (to use the words of Professor Lewis and Louis Pasteur) through *action*.

(b) For a discussion of evolution in relation to Christianity the reader is recommended to a work by biologist David Lack entitled "Evolutionary Theory and Christian Belief "[21].

(c) Accepting that Man is a part of nature, psycho-analysis gives one of the closest scientific approaches to an understanding of his nature.

(d) The "powerful expositions" quoted by C. S. Lewis correspond to our reasons for rejecting Sherrington's evolutionary philosophy.

(e) The imagery of nature as portrayed in this extract corresponds to the symbolism inherent in Jung's concept of the collective unconscious. According to Jung the collective unconscious is " the all-controlling deposit of ancestral experience from untold millions of years, the echo of prehistoric world events to which each century adds an infinitesimally small amount of variation and differentiation ". The deposit of the racial past provides what Jung calls " a living system of reactions and aptitudes determining the individual life in invisible ways ". These ancient systems of reactions show themselves in the form of archetypes, or images, which express them in the manner of meaningful symbols. (As Jung himself said "As the body is a sort of museum of its phylogenetic history, so is the mind. There is no reason for believing that the psyche, with its peculiar structure, is the only thing in the world that has no history beyond its individual manifestation "). The archetypes may appear as persons. They may appear as natural forces and objects, or they may appear as geometrical forms, numbers and the like, the symbolic meaning of which has been known to esoteric lore through the ages in all countries. Two things are worthy of note here. Firstly, Ruth Munroe admits an unusually long series of direct quotations in her coverage of Analytical Psychology and " freely confesses " the reason—that she is not able to form a reliable personal opinion about what Jung actually means by the collective unconscious and deep inheritance of mankind. In a technical discussion of the matter she remarks that Jung sometimes writes as if Freud's unconscious were a paltry affair, consisting entirely of rather concrete childhood experiences, subsequently repressed: as if the process of repression took place as a consequence of difficulties appreciated at a quasi-adult level of sophistication. For reasons such as this, and because it seems to fit the contemporary scene outside psychoanalysis better, we have selected the analogy drawn by Dr. Stafford-Clark to represent Jung's Collective Unconscious.

Secondly, one of the latest Gifford lecturers, Professor Hardy, places reliance upon the evidence of social anthropologists who have made a study of the religions of primitive man all over the world.

(f) Communication with a transcendental Being by prayer is not limited to Western religions: Eastern mysticism achieves this, *and* Professor Hardy sees this and extra-sensory perception as the two methods of achieving this communication in " The Living Stream " (a collection of Gifford lectures on *Natural Theology).*

In his book " The Four Loves " C. S. Lewis disentangles man's need for God from his need for his fellow men and outlines two kinds of nearness to God: nearness by Resemblance and nearness by Approach. He also constructs an elaborate classification of the differing kinds of " love " e.g. Friendship, Charity, Affection and what he calls " Eros ". In the following quotation he mentions these and also refers to a couple of philosophies which accepted Eros as something actually transcendent. " Neither the Platonic nor the Shavian type of erotic transcendentalism can help a Christian. We are not worshippers of the Life Force and we know nothing of previous existences. We must not give unconditional obedience to the voice of Eros when he speaks most like a God. Neither must we ignore or attempt to deny the God-like quality. This love is really and truly like Love Himself. In it there is a real nearness to God (by Resemblance); but not, therefore and necessarily, a nearness of Approach. Eros, honoured so far as love of God and charity to our fellows will allow, may become for us a means of Approach".

There are in Professor Lewis's classification further sub-divisions of love into Gift-love and Need-love (this includes a supernatural Need-love of Himself and a supernatural Need-love of one another). An example of Gift-love would be that love which moves a man to work and plan and save for the future well-being of his family which he will die without sharing or seeing; of the second, that which sends a lonely or frightened child to its mother's arms. Need-love is the accurate reflection in consciousness of our nature. We are born helpless. As soon as we are fully conscious we discover loneliness. We need others physically, emotionally, intellectually; we need them if we are to know anything, even ourselves.

C. S. Lewis points out that a strange corollary follows his definition of Need-love, " Man approaches God most nearly when he is in one sense least like God. For what can be more unlike than fullness and need, sovereignty and humility, righteousness and penitence, limitless power and a cry for help? This paradox staggered me when I first ran into it; it also wrecked all my previous attempts to write about love. When we face it, something like this seems to result". Here we have another example of the emphasis placed by Christianity upon extremes of behaviour.

Jung saw a *balance* of polarities such as these as essential for a healthy life. "As the person relates himself to the world around him, the libido takes two general directions. One direction, which Jung calls introversion, is towards the self; the other, extroversion, is towards the outside world. The one is essentially subjective in its orientation; the other objective. Clearly both directions are necessary to wholeness of living. Although complementary, they tend to function in opposition . . . Jung recurrently stresses thesis and antithesis, a philosophy of opposites which require reconciliation ". An important point is that both introversion and extroversion are *necessary* directions for the libido in establishing relations between the persons and the outside world. Overly exclusive development in either direction brings about *un*conscious development in the other. The more "pure" the conscious expression of one type, the more inevitable becomes the unconscious antithesis. For Jung maturity lies in harmonious integration, not in development along a single line, however virtuous it may appear. We may contrast this with C. S. Lewis on Eros: " . . . Our conditional honour to Eros will of course vary with our circumstances. Of some a total renunciation (but not a contempt) is required. Others, with Eros as their fuel and also as their model can embark on the married life, within which Eros, of himself, will never be enough—will indeed survive only in so far as he is continually chastened and corroborated by higher principles".

One final point concerning C. S. Lewis: he writes of spiritual Evil as well as spiritual Good and of unholy as well as holy angels (in similar vein to Dr. Mathews, Dean of St. Pauls, whose writings are also recommended to anyone seeking further information). We could, perhaps, suggest that our plexus of equations is capable of enlargement to include relations such as

$$-(\text{divinity}) = \log\ (\text{malevolence}).$$

The background to a relationship of this nature is chillingly described in C. S. Lewis's " The Screwtape Letters "[22] and in his " Perelandran " trilogy. We might also add that the balance of introversion and extroversion in a mature individual in Jung's scheme is a parallel to the " middle path " precept of Buddhism.

Talked of in such terms it does not seem impossible that the common truths could ultimately be disentangled from the web of interpretation that has been spun around them. The division of opinion becomes the more irreconcilable as the religions (including Buddhism) become bedecked with trimmings. In " Evolutionary Theory and Christian Belief ", David Lack summarizes in 10 points what may reasonably be concluded from the evidence of evolution and admits that they do not take us nearly far enough for deciding the basis of our lives and conduct. The tenth point is as follows: " Science has not accounted for morality, truth, beauty, individual responsibility or self-awareness, and many people hold that, from its nature, it can never do so, in which case a valid and central part of human experience lies outside science. But if man evolved wholly by natural means, it might be supposed that all human nature should be interpretable in scientific terms. It might therefore be argued that man cannot have evolved wholly by natural means. But others would disagree, since there are unbridged gaps and unreconciled contradictions in every view of the meaning or lack of meaning, of the universe ".

Lack continues " . . . Hence the question is, which set of gaps and contradictions is to be accepted. A Christian agreeing to man's evolution by natural selection, has to add that man has spiritual attributes, good and evil, that are not a result of this evolution, but are of supernatural origin. A secular humanist, likewise agreeing to evolution by natural selection, accepts the validity of morality, truth and beauty, while acknowledging that their genesis cannot yet be established. At the present day, both these views are honestly held, and one need not doubt the integrity of either Christian or agnostic biologists. On the other hand, it is extremely hard to maintain that moral and other values are, or could be, a product of biological evolution, or alternatively that because they are inexplicable in terms of science, their value is illusory and should be disregarded ".

Elsewhere Lack writes "Because the rational arguments for Christianity are by no means compelling, it seems necessary to add personal religious experience which to some is totally convincing and by others is unfelt or deemed an illusion. For its adherents the acceptance of Christianity is an act of faith". He then quotes J. H. Newman, who said in a sermon in 1839 "... faith is a principle of action, and action does not allow time for minute and finished investigations". We have remarked previously how action seems to be an element common to all philosophies. As Jung said: Is there any better truth about things than the one which helps you live? J. H. Newman also advances succinctly an argument similar to Professor Hanson's. "Half the controversies in this world are verbal ones, and could they be brought to a plain issue, they would be brought to a prompt termination . . . when men understand each other's meaning, they see, for the most part, that controversy is either superfluous or hopeless".

Another common element seems to be that we can in some way communicate with God. Although Sherrington wrote that his interpretation of Natural Religion favoured a one-way relationship between the Observer and the Observed, Hardy some thirty years later pronounced a transcendental interpretation of Natural Religion. Sherrington wrote: "The great religions as part of their anthropomorphism cultivate the Deity as a personal Deity. But this source of emotional strength Natural Religion is without, for it sublimes personal Deity to Deity wholly impersonal". Professor Hardy rejects all orthodox dogma including the Resurrection and doubts whether, if Jesus were living to-day, he would call himself a Christian. But he points out that "The overriding impression from all these studies of the religions of primitive man from all over the world is that he is conscious of being in touch with some Power which appears to be outside and beyond the individual Self and from which he can receive grace: help in the conduct of his life and a sense of renewed vitality". Hardy finds these conclusions sustained in William James's "The Varieties of Religious Experience", in the works of Jung, and other psychologists. As for Freud, he concedes that man's image of a Father in Heaven may be strongly coloured by love and fear of his father on earth; but the crucial point for Hardy, as for David Stafford-Clark, is that the equation of the Freudian Super-ego with the idea of Divinity cannot be complete, and does not destroy the reality of the spiritual experience. In a similar way, sexual feelings and sado-masochistic aberrations may get mixed up with mysticism, but they are by-products, not its essence. The essence, in Hardy's view, is the irreducible experience of what Richard Otto called the numinous, the "mysterium tremendum et fascinans". These descriptions of Hardy's views are taken from Arthur Koestler's review of "The Living Stream".

Koestler's comments on Hardy's views are as follows: "Whatever one's attitude, one cannot but be deeply moved by this act of faith. It is beyond the reviewer's competence to decide whether God exists. All he can do is to state his personal bias, that only a fool would deny dimensions of reality unknowable to man, which may add up to a coherent whole, but that only a saint would attribut to it the qualities of benevolence and love. For all we know the "anima mundi" might be a Portuguese man of war. Professor Hardy's God certainly bears no anthropomorphic features, but also shows no trace of cruelty. The most obvious criticism to be levelled against his book by believers and unbelievers alike is that except for a few passing mentions, it evades the question of evil".

Possibly because Hardy's views are similar to our own, his reference to sado-masochistic aberrations seems to indicate adequately enough the position of suffering and evil in his scheme of things: Koestler's point about the Portuguese man of war is not worthy of discussion. In our modified version of Plato's scheme, i.e. some entelechic system, evil could be the manifestation of a change in direction—analogous to Feynman's positron theory: this agrees well with studies of social adjustment and maladjustment. In a Pantheistic scheme suffering is comprehensive—God suffers too: Buddhism also provides an explanation of suffering. Both of these systems would have the advantage of autonomy. An observation which seems filled with implications is that there seems to be no overt system in nature where man can individually atone for the sins of others, or for the transference of suffering. Traditional answers that these are inscrutably divine character-building methods seem inadequate: and yet how often does one see "character" transcend suffering; and it is truly astonishing how often "chickens come home to roost" and one appears to "reap what one has sown". Again, how does one equate this and freedom of choice with what we know of conditioning and learning? It does not seem impossible that in some cases divine intervention or guidance may occur—possibly of the sort so well illustrated by C. S. Lewis in the "Perelandran" trilogy and in "The Horse and his Boy". This opinion is shared by Donald Mackay (see footnote) who, similarly to C. S. Lewis, talks in terms of God the Author. Mackay overcomes difficulties of this kind by drawing a distinction between God the Author and God the character revealed in the plot. A distinction between God-in-eternity and God-in-

dialogue, as he calls it, which has suggestive resemblances to that which Christian theology maintains between the different " Persons " of the Godhead. He suggests that what we have is the freedom to *change* rather than freedom to choose; of freedom to become different from what we are, and perhaps more like what in our better moments we want to be. This makes good complementary reading (i.e. scientific rather than mystical) to the works of C. S. Lewis, and accords with the philosophy of Jung—we may note that of the psychoanalytic doctrines Jung's Analytical Psychology is most acceptable to the Catholic Church.

To sum up on Religious needs we may refer to the opinions of Freud and Jung as related by David Stafford-Clark in "Psychiatry To-day".

"Psychiatry can help us to break bonds which have hitherto confined our knowledge, but it cannot really set a limit to what we can know or believe. Freud, dealing with one piece of evidence which had been offered to him as the ultimate source of religious sentiment, namely a subjective sense of awareness of eternity, of something limitless and unbounded, of some indissoluble connection with the nature of reality itself, remarked, 'These views . . . put one in a difficult position. I cannot discover this oceanic feeling in myself. But I cannot on that account deny that it in fact occurs in other people'. Such a denial would have been unwise and moreover impossible to sustain, because this subjective experience is a recurrent and undeniable reality for a great number of people. It seems to be at the core of all mystical experience, and whatever its nature it is not something which psychiatry or any other scientific procedure can explain, still less explain away. Jung has written of it: '. . . I must point out that there is no question of belief, but of experience. Religious experience is absolute. It is indisputable. You can only say that you have never had such an experience and your opponent will say " Sorry, I have ". And there your discussion will come to an end. No matter what the world thinks about religious experience, the one who has it possesses the great treasure of a thing that has provided him with a source of life, meaning, and beauty and that has given a new splendour to the world and to mankind . . . Where is the criterion by which you could say that such a life is not legitimate and that such experience is not valid . . . ? Is there, as a matter of fact, any better truth about ultimate things than the one which helps you to live ? '

"It is this which links the discussion of psychiatry in relation to art, and particularly to genius in art, to the discussion of its relationship with religion and philosophy. For there is a part of genius which would appear to be abnormal only in the sense that it is super-normal, or, if you like, supernatural. It is the revelation which corresponds in the artist to the experience of supreme awareness in the mystic. Where the person who receives this gift or inspiration is an artist as well as a mystic, as were, for example, Blake and Emily Bronte, the outcome is not only genius but genius with a particularly passionate and deeply religious aura. It would perhaps be possible for a psychiatrist to approach and to understand the human element in this kind of creation; but he would be no better and no worse placed than anyone else to appreciate that other than human element which many will call divine. Nor has he any right whatever to pretend that anything he knows casts reasonable doubt upon such divinity. There is nothing about a belief in psychiatry which makes impossible a belief in God, and nothing about a belief in God which makes impossible a belief in psychiatry. The part is not greater than the whole."

Conclusion

In this series of papers we have shown many points of agreement between the psychical universes conceived by Professors Burt and Jung and the bio-physical universe about us. Enough, it is felt, to provide convincing support for the three "suggestions" we proposed adding to Dr. Good's " technique " of probability. From our discussions a plexus of equations has formed which may be set against a background of energy, entropy and information theory or, alternatively, may be expressed in terms of a general life-process, and other processes by which an organism may adapt to its environment. These equations are widely and deeply rooted in the bio-physical world and yet, by virtue of the above agreement, they may be broadly correlated with the philosophies of Burt and Jung. The equations (including ones tentatively advanced as examples) are as follows:—

−(entropy)	$= k \log (^1/_p)$	Schrodinger
−Sensation	$= k \log (R)$	Weber-Fechner
−F(x)	$= k \log (^p/_q)$	Logistic
—Plausibility	$= k \log$ (odds)	Good
−(morality)	$= k \log$ (self-interest)	Sturgeon
−(divinity)	$= k \log$ (malevolence)	Lewis

The latter two, for convenient reference, are named after the authors who have afforded the best description of the circumstances we have envisaged.

Footnote:—Donald Mackay is Granada Research Professor at Keele University. He is a physicist working on the mechanisms of the brain and he makes these similes in the twenty-first Arthur Stanley Eddington Memorial Lecture, delivered at Cambridge University in November 1967. (The lecture is published by Cambridge University Press—price five shillings—under the title " Freedom of Action in a Mechanistic Universe ").

As well as this general correlation there are further features of Jung's theory of the personality which may be closely and specifically correlated with the Weber-Fechner, Logistic and Good, equations—even to the extent of a matching vocabulary. We have referred to the Weber-Fechner and Logistic equations, in particular, in terms of balanced processes involving sensation, or apprehension, and judgment, respectively, against a background of unconscious, intuitive and emotional aspects of scientific inference. Jung writes of a balance between two general "attitudes" of the personality and to these he adds four "functions": sensation and intuition (modes of apprehension) and feeling and thinking (modes of judgment). The context of both might be said, broadly, to concern the adaptation of the individual to its environment. The logistic function was originally discovered by Verhulst during a search for a single equation to describe development taking place in the midst of obstacles of all kinds which tend to arrest it. (How well this fits Ruth Munroe's "view of systems" as well as Jung's concepts). We see that (even allowing for the dangers and difficulties described by Grey Walter and Ruth Munroe) there is a close correspondence in language, in classification and in context.

Thus we are able to specify a comprehensive range of correspondence between the above equations and the concepts postulated by Jung in his theory of Analytical Psychology. If we follow Jung's subdivisions and consider first the universal unconscious, then the relationship of the individual to his own self, to his fellows and to the extra-terrestrial energy of life, we can set this out as follows:—

(a) The universal unconscious—difficult to define and open to a variety of interpretations—we can suggest corresponds to the physical substratum emergent in particle physics and amenable to description in numerous respects by the logistic function and its transformation.

(b) The four "functions" of the personality, sensation and intuition (modes of apprehension) and feeling and thinking (modes of judgment) correspond to the adaptive, inferential equations—the Weber-Fechner, Logistic, Good equations—representing sensation, or apprehension, and judgment in relation to intuition and emotion.

(c) The balance of "attitudes" (introversion and extroversion) postulated by Jung we can equate to the balance between order and electrical energy on the one hand and mathematical space, or the Transfinite, on the other[23, 24]. A balance, say, between spirituality and earthiness (a simile that seems in keeping with examples given by Jung to illustrate the balance between the *directions* the libido may take).
Otherwise, we can equate these opposing directions to the polarities introduced by the change of sign which converts a set of relative "weights of evidence" into "amounts of information"[1], or to the change of sign we have noted[24] in the particle distributions as they cease to describe numbers of electrons and begin to describe "phonons". Alternatively, we can relate this balance to the "balance" referred to in Ref. 23 between psychical and physical components of an organism, and the possible representation of this by logistic curves. A major aspect of Jung's theory is that every individual has *within himself* the counterpart of the predominant attitude. The more consciously and exclusively he develops his natural bent, the greater the *un*conscious development of its opposite. The fundamental process effecting the balance would then be that described by Gunther and Campbell which eliminates the quantization of matter—shown by symbolic logic to be possible and to lead to the realm of the Transfinite—and which adds to the three parameters recognised to-day — Matter, Space and Time—a fourth *cosmical* component, the operational parameter, P. This we suggested might be called a subjective component[24].

(d) Jung based his theory on the scientific investigation of groups and we can advance an equation to cover morality and the group. As we have seen, the logistic is widely used as a function describing population growth. We have already demonstrated an analytical use for it and given an example of the type of sociological application for which it could be used[24]. The example featured population growth in the suburbs of a large city and it is easy to see how it could be extended to cover morality (e.g. by taking religious beliefs as a measure of morality ?).

(e) Jung means by the libido a life energy underlying all natural phenomena, including the human psyche—apparently rather similar to Bergson's concept of the "elan vital". It is at once more monistic and more pluralistic than Freud's meaning. The principle, the LOGOS, which forms and differentiates, which brings order out of chaos, which strives for mastery and competence, we can align with Schrodinger's equation derived to represent an analogous life process—the way an organism regulates the order of its

environment, and separates and differentiates in its behaviour pattern.

(f) (i) We can also suggest a relation (consistent with the plexus but probably untestable) to correspond to the other principle postulated by Jung, the EROS—the principle of relatedness and receptivity, the tendency to love and nurture the potentials of life. This, of course, is the Lewis equation. We note how well it agrees with Mackay's desire for "improvement".

(ii) Furthermore, a scheme of things can be suggested within which such a relation would obtain, i.e. the contemporary Platonic system of entelechy embodying the primal urge for completion. This would be consistent with the plexus, would be in context, and would have appropriate mathematical and physical connotations.

Previous comments in this paper taken with past identification of the word LOGOS with Jesus Christ, the Act of Creation, Plato's concept of Mind, and the *philosophical* aspects of the Trinity, together with Professor Mackay's comment on the Trinity, render this, also, an "apt" suggestion. In the "elan vital", the "LOGOS" and the "EROS", may be seen the concept of the Trinity. We may see this, as would C. S. Lewis, as a hint of the uncreated given in the created, or we may see it as a Pantheistic property which has given rise to a belief in the Trinity, or, possibly, we may attempt to reconcile the two outlooks by considering much of the Christian gospel as allegorical and presented in a form comprehensible to the audiences of the time, but at this point we must stop. Although we are still interested (from the point of view of prediction among others) in which of the pictures is correct (if any be), to go further would be to stray too far from our subject. From hereon each must rely on his own subjective judgment. We have pursued our enquiry to its outer limits: to the point where judgment becomes an act of faith.

Acknowledgements

This series of articles results from the private reading and work of the author and represents a personal contribution to the R.N.S.S. Journal. The author is indebted to Dr. R. A. M. Bound for comment and encouragement and to Dorothy Baron for enthusiastic help in preparing the report.

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[23] "Probability, Judgment and Mind 2 (Part 2)" by K. W. Harrison. *R.N.S.S.* Journal.

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TUG CONFERENCE

An International Conference (with the theme of Towage, Tugs, Lighterage and Integrated Cargo Units) is to be held at The National Physical Laboratory, Teddington, Middlesex, on the 7th - 9th of October, 1969. The registration fee of £21 entitles delegates to participation in the technical sessions, a set of conference papers, and the Proceedings.

Further details are obtainable from: The Editor, Ship and Boat International, 39 St. Andrew's Hill, London, E.C.4.

FREQUENCY CONTROL AND RECEIVER TECHNIQUES

A. Cormack

Racal - BCC Limited

SSB working was introduced into h.f. Naval Communications well in advance of the mandatory requirements, and data communication systems are already in use.

It is desirable that communications should be maintained using unattended equipment and these communication techniques require that both receivers and transmitters are capable of a frequency stability measured in Hz per month, and for some data systems a phase stability measured in degrees per second.

There are two basic methods which Racal have adopted to meet the stringent frequency and phase requirements.

(1) Their use of frequency synthesis techniques and
(2) Their Racalator principle or drift correction techniques.

Frequency synthesis is now well established, but our work is aimed at greater simplicity giving more reliability in operation and units of low initial cost. A further area of advancement is concerned with faster switching times and higher purity of oscillator signal.

It has been generally accepted for many years that the superhet principle should be used in all receiver systems. The stability of the receiver is therefore determined by the frequency of one or more oscillators. Since the early 1950's, we have been using the now well-known triple-mix drift cancelling principle giving a measure of frequency synthesis at low cost. The overall frequency stability, using this principle, is dependent on the stability of a master frequency reference source, with a free-running local oscillator operating over a relatively narrow frequency band. A free-running local oscillator has a major advantage to the user, in that complete flexibility is available allowing any frequency to be chosen, but even the best design has a stability which is well outside that required for long-term reception of S.S.B. or digital signals. The new "Racalator" principle enables the advantages of flexibility to be retained, but gives a long-term stability which is determined only by the master reference source. Fig. 1(a) and 1(b).

The basic operation of the Racalator consists of counting the free-running oscillator frequency and storing the information. The stored information is compared with the measured frequency a short time later and a correction voltage is applied to retune the oscillator frequency to that originally measured.

During the last few years a major advance in synthesizers has taken place Fig. 2 due largely to an advance in digital circuit techniques and the availability of low-cost semiconductor integrated circuits. As an example of what can now be done, we already have in quantity production a synthesizer covering a 6 MHz range in 1 kHz steps which sells for under £500. This compares with £1,250 and more being paid for h.f. synthesizers. Another synthesizer which will be in production within the next year covers the full HF spectrum in steps down to 1 Hz, and is capable of being switched in less than one second, but for small frequency steps times better than 10 milliseconds can be achieved.

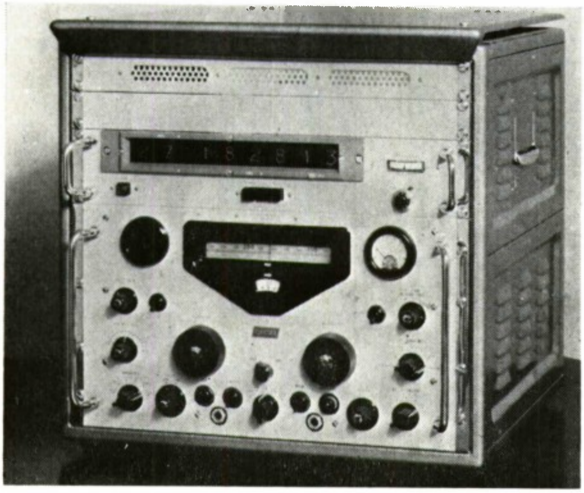


FIG. 1(a). 'Racalator' MA.210 frequency stabilizer shown mounted in a cabinet above an RA.17 H.F. receiver.

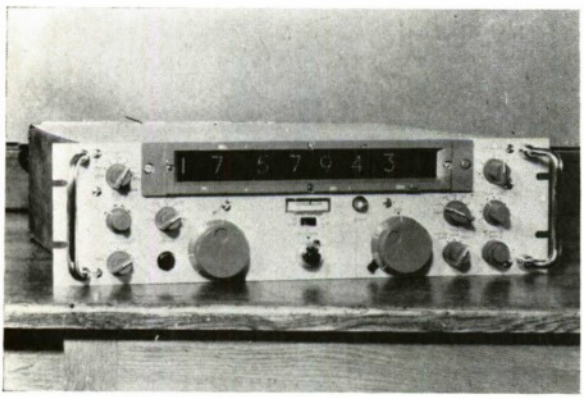


FIG 1(b). RA.1219 transistorized H.F. receiver with electronic digital frequency display, and stabilized control of selected frequency.

Design Improvement. The last major ship fitting programme in the British Navy was based on a fully valved synthesized receiver. At the time this equipment was developed transistors were freely available, but the very difficult radio environment aboard ship precluded their use. The basic problem is that the modern fighting ship requires the simultaneous operation of a number of high-power transmitters, and spacing between receiver and transmitter aerials must, by necessity, be very small. Many signals are therefore picked up on the receiving aerial having magnitudes in excess of 10 volts. Unless all active components are adequately protected and have substantially linear characteristics, these signals can produce very many intermodulation products, thus blocking a large number of receiver channels. Semiconductor techniques have now advanced to the point where non-linearity is sufficiently reduced to permit their use.

A word of warning must be given at this stage that it is possible to overspecify the receiver performance, resulting in unnecessarily long development and costly equipment. Intermodulation takes place in the structure of the ship, and there is little point in the receiver having a better spurious response performance than is inherent in the ship itself. Some years ago, during trials aboard one of H.M. ships, strong intermodulation products were detected, it was found that these were due to intermodulation products being generated in a passing tanker and it became clear that the performance of the receiver was, in fact, better than that required in practice.

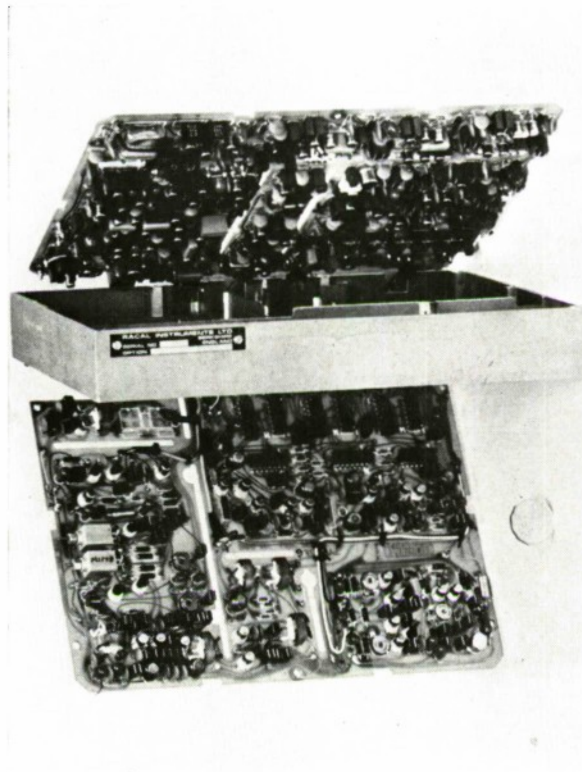


FIG. 2. Frequency tuning and synthesizer unit from the TRA.921 'Syncal' H.F. S.S.B. Manpack.

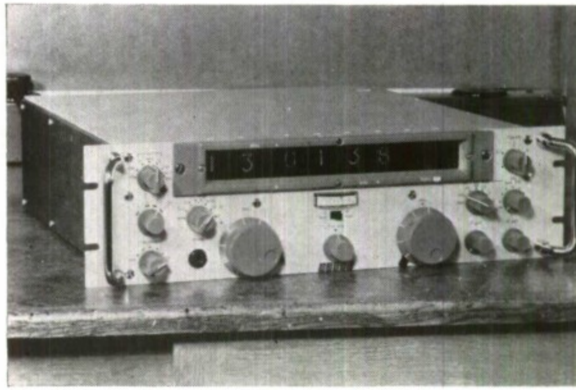
Modern receiver design has taken into account the need for ease of maintenance and consequent low time to repair. Various estimates have been made of the costs of maintaining electronic equipment throughout its working life. These have indicated that where modular construction is not used approximately ten times the initial capital cost is expended in maintenance. This figure does not take into account any loss of revenue which results from the time that the equipment is out of commission. By using a modular construction which permits easy replacement of the faulty part of the equipment, the costs can be considerably

reduced and estimates have indicated that maintenance costs can be reduced to the order of three to four times the capital cost of the equipment. The capital cost of the equipment is increased using this constructional form but this increase is likely to be less than 20%. In our current range of equipment the modular concept is employed and it has been shown that with very simple internal and external checking facilities the faulty module can be identified and replaced in less than half an hour.

The M.T.B.F. for a typical complex receiver has been calculated at approximately 5,000 hours and field experience to date confirms that this figure is achieved in practice.

The Racal 217 series of receivers uses a modular concept. It has been in quantity production for the last two years. It has a frequency of 1 to 30 MHz and is fully transistorized; sensitivity, measured in a 3 kHz bandwidth, is 1 μV e.m.f. for a 15 dB S/N ratio on c.w. or s.s.b.; using m.c.w. or d.s.b. it is 3 μV for a 15 dB S/N ratio, when modulated 30% at 400 Hz. The frequency setting is indicated on an easily-read in-line digital display, enabling quick and accurate selection of the desired frequency. Four alternative i.f. filters (3 dB bandwidths) are provided at 13, 3, 1 and 0·2 kHz. An interfering signal 20 kHz removed which is 45 dB above the wanted signal will produce a cross modulation figure of less than 3%. Intermodulation figures are typically 80 dB for 2 signals 10% removed, and an unwanted signal 20 kHz removed must be 56 dB above the wanted signal to reduce the output by 3 dB. The operating stability after two hours from switch-on is $\pm$50 Hz over an 8-hour period at constant ambient temperature and humidity, with calibration accuracy better than $\pm$1 kHz. Facilities are also provided for the use of an external synthesizer or other external frequency control. The RA. 1217 is a rack-mounted version of the same equipment using identical electrical modules to the RA. 217, only two having to be repackaged to suit the available space. It occupies only $3\frac{1}{2}$ inches in a standard 19-inch rack.

FIG. 3. RA.217 transistorized H.F. receiver, with cover removed showing modular construction technique.



RA.1218 transistorized H.F. receiver with electronic digital frequency display.

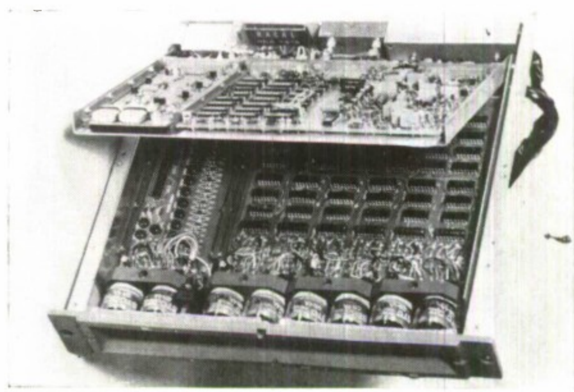


FIG. 5. Synthesizer unit and electronic frequency digital display of the RA.1219 H.F. transistorized receiver.

The next stage in development of the Racal receivers was the RA. 1218 which incorporates an electronic frequency meter giving a frequency readout $\pm$10 Hz. It is basically the RA. 1217 receiver, but now occupies $5\frac{1}{4}$ inches in a standard 19-inch rack. The frequency indication is obtained from the first and second v.f.o's of the receiver; the first two digits are encoded from the drive shaft of the first v.f.o., the last five digits are obtained by accurate measurement of the frequency of the second v.f.o., by a counter which uses silicon integrated circuits and is referred to an inbuilt frequency standard which has a stability of 1 in 10^6 per month. If greater accuracy is required, an external frequency reference for the counter may be employed.

A new microelectronic receiver using the latest constructional techniques is in an advanced stage of development. This receiver, which may be remotely-controlled, has been designed specifically to meet Naval requirements, having low intermodulation products with low spurious responses, and it is controlled from a fast-switching synthesizer. A modular construction is again being used, but now each module is in thick-film form, embodying semi-conductor integrated circuits offering maximum reliability. Frequency range covers the high-frequency communications band, with capability of extension to both low-frequency and medium frequency bands. All controls are electronically actuated, no mechanical parts being employed. To offer some idea of size reduction achieved, the new microelectronic receiver and remote control unit is approximately one-fifteenth of the size of those of its predecessor, the "Speedrace" remotely-controlled receiver.

The space model shown will give some idea of the layout employed.

The new receiver will find many applications throughout the whole range of radio communications, not merely being confined to the shipborne environment for which it was originally designed. The Racal *Redac* computer-aided design service has greatly assisted in the development of this receiver, both in circuit design and in design of thick-films.

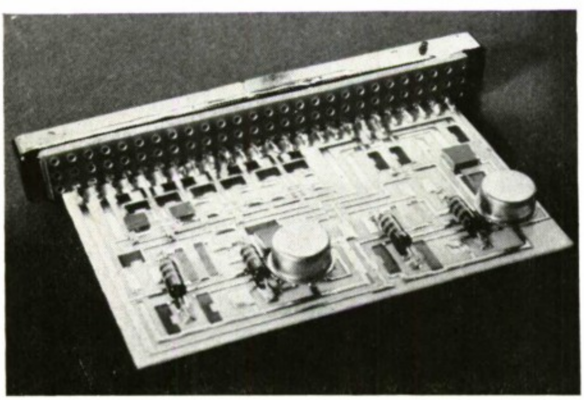


FIG. 6. Thick film circuit and discrete components prior to encapsulation.

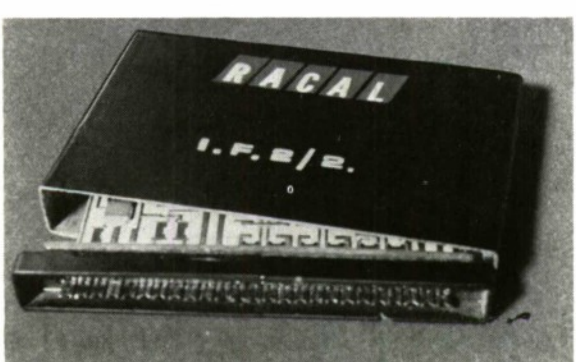


FIG. 7. Thick film circuit, with discrete components added, being inserted into its encapsulation.

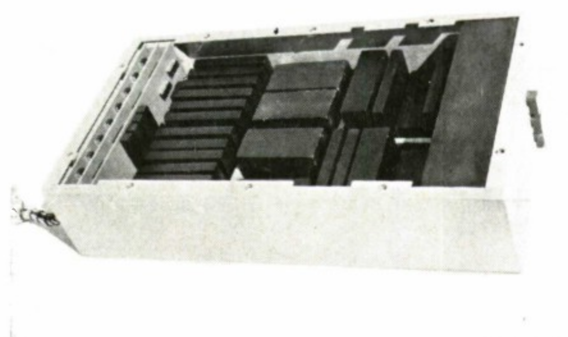


FIG. 8. Space model of the micro-miniature receiver.

As mentioned earlier, the "Racalator" (and its operator controls) was to be explained. The principle of operation of the "Racalator" is quite simple. It provides a separate digital electronic frequency indicator and controller for the receiver, frequency indication being by nixie-type tubes. The operating frequency of the second v.f.o. of the receiver is measured and indicated as the operating frequency of the receiver, by incorporating a standard frequency offset at the intermediate frequency of the receiver. The actual operating frequency of the v.f.o. is measured, and this measurement is stored in a memory circuit. The operating frequency is again measured, about one second later, and this measurement is subtracted from the measurement result stored in the memory. If both measurements are identical, there is no difference number produced. If the two frequencies do differ, however, a difference number will be produced. This number is applied to a digital-to-analogue converter, producing a d.c. voltage output, whose magnitude and sign are proportional to those in the difference number. This d.c. voltage is used to control a varactor placed in parallel with the frequency-determining circuit of the v.f.o. and restores the v.f.o. to the original operating frequency. In addition, by using the offsetting technique, the electronic counter displays the current operating frequency of the receiver, using the successive frequency measurements obtained from the control process. The operator will also find the "Racalator"

simple to operate. First, the required signal is tuned-in, using the normal controls of the receiver, shown in Fig. 1(a)—an RA. 17—and observing the electronic digital frequency readout on the front panel of the "Racalator", with the main "Racalator" control set to COARSE. With the main control now set to FINE, the FINE TUNE control of the "Racalator" is adjusted to obtain the desired operating frequency indication on the "Racalator" display. The main control is now set to HOLD, which maintains the operating frequency of the receiver accurately, at that which was originally indicated at the end of the FINE TUNE operation. The frequency is stabilized almost indefinitely within $\pm$ 3 Hz.

Another interesting Racal development is the synthesizer used in the TRA. 921 "Syncal" h.f. manpack (Fig. 2). This covers the frequency range 2 to 8 MHz, providing 6,000 operating channels which are spaced by 1 kHz. It is a very compact synthesizer, consisting of two major printed-circuit boards, which have been designed to fit into a modular partitioned shield. It is extremely light in weight, and its power consumption is about 1 watt only. It does not need the ultimate in switching speed, but frequency changes are completed in less than 1 second; in practice, the time to change frequency is dependent upon the speed of the operator. This synthesizer incorporates a temperature-controlled crystal oscillator which has a stability better than $\pm$ 30 Hz between $-10°$ and $+55°$C, which is adequate for the service envisaged.

The stability and accuracy of the equipment will always remain equated to the higher quality and operating conditions of the control crystal. Future communication systems will inevitably require an even higher order of long term accuracy and stability and improvement in output waveform purity.

It is confidently anticipated that these requirements will be met by the availability of very close tolerance components which are now in course of design and manufacture.

In general terms communication problems and solutions for the u.h.f. band are similar to those for equipments and techniques used in the h.f. band.

NAVAL RESEARCH AND DEVELOPMENT ON DISPLAY

"Navy Days" 1969

Following the successful exhibition of Naval Research and Development last year, the R.N.S.S. has again been invited to participate in the 1969 Navy Days to be held in Portsmouth dockyard from Saturday, 30th August to Monday, 1st September inclusive.

The venture will be supported by *A.E.D.U.*, *A.E.L.*, *A.E.W.*, *A.O.L.*, *A.S.W.E.*, *A.M.L.* and *C.D.L.* We are confident, after the experience gained last year, that the exhibits will again excite the considerable interest of the public. The display site will be in and around the *Victory* repair shop.

N.C.R.E.

The Naval Construction Research Establishment at Dunfermline, Fife, is for the first time to hold "Open Days" from 23rd to 26th September 1969 inclusive.

Amongst the unique facilities on view will be a large testing frame (70 ft. $\times$ 33 ft. $\times$ 39 ft.) in which an $\frac{1}{8}$ scale model of a supertanker will be tested. This will be associated with the structural analysis of the hull design of the 400,000 and 1,000,000 tons dwt. supertankers now being carried out in collaboration with Ministry of Technology and the Shipbuilding Industry.

Other research work to be displayed will include the effect on ships machinery and equipment, of shock resulting from underwater explosion; investigations into noise and vibration reduction; special composition steels; welding processes and the use of plastics for stress analysis and hull design.

Retirement

J. M. KIRKBY

At the age of 68 Mr. Kirkby retired on 31st March 1969, after 32 years in Admiralty Service. He was educated at Cambridge University where he read Engineering and obtained an M.A. degree. On leaving University he went to B.T.H. Rugby where he was awarded a B.T.H. Fellowship for one year's experience in the U.S.A. On his return he was employed on production at B.T.H. until the end of 1936.

Dr. Butterworth (left) making the presentation on behalf of colleagues.

In January 1937 he joined the Admiralty as a Technical Officer at the Mine Design Department, H.M.S. *Vernon*. Most of 1940 he spent at Bath as Superintendent, Mine Designs representative for production of the North Sea mine barrage. In 1941 Mr. Kirkby took over responsibility for Depth Charges on which he continued for the rest of the war. Mr. Kirkby was promoted to P.S.O. at the Reconstruction in 1946 and took over the Mine Countermeasures from Sweeping Division until 1961. During this period the work grew from two men (the remnants of Sweeping Division transferred to Havant) to a team of 20, with top priority projects and dwindled again as likelihood of mine warfare in narrow seas receded. He was promoted to S.P.S.O. in July 1958 and in 1961 he took charge of Workshops and Drawing Offices at A.U.W.E. as Head of Engineering Services Division.

Apprentice presentation.

In 1966 (November) he was disestablished and re-employed as S.S.O. when he became Training Officer, from which post he retired. On his retirement he was presented with two pieces of silver, a cream jug and a sugar basin, by his colleagues. The apprentices also marked the occasion by giving him an electric drill for all his help and encouragement to them.

Retirement

A. J. WHYMARK, R.N.S.S.

Mr. A. J. Whymark, Experimental Officer, Central Dockyard Laboratory, retired on the 25th March 1969 after 48 years continuous service with the Admiralty.

He entered Portsmouth Dockyard as a founder apprentice in 1921, and after completing his apprenticeship in 1926, he divided his time between the laboratory and the foundry floor. In the laboratory he was responsible for the scientific control in connection with steel production from electric arc furnaces. During the mid-thirties he became a member of the Engineering Department's Metallurgical section, later to become the Central Metallurgical Laboratory. In 1939 he was in charge of the Foundry Laboratory as a T.E.A.III. He remained in charge until his retirement this year, being made an experimental officer in 1946 during the reconstruction.

The Superintending Scientist, Dr. E. N. Dodd, presented Mr. Whymark with a transistor radio on behalf of the staff and thanked him for his loyal service and valuable contribution he had made in the Foundry. Mr. Whymark in reply thanked both present and past members of the staff for their helpful co-operation and assistance.

His many friends will wish Alfred Whymark a long and happy retirement. Alfred, earlier in his career, was well known in local football and cricketing circles. He skippered the local Civil Service Sports Association XI for 12 years and was secretary for 15 years. We are all sure that his sporting instincts will come to the fore and he will spend many happy hours on the bowling green during his retirement.

THIN FILMS WORKSHOP MEETING ON CLEAN SURFACES

18th September, 1969

University of Southampton

The Thin Films Committee, representing the Electronics, Electron Microscopy and Analysis, Magnetism, Optical and Vacuum Groups, is organizing a one-day conference on CLEAN SURFACES at the University of Southampton, on Thursday, 18 September 1969. Attendance will be by invitation and limited to 50 persons. Accommodation for the night of 17 September will be available in a University Hall of Residence. Members, and others, wishing to be considered for an invitation should write for details and an application form to the Meetings Officer, The Institute of Physics and The Physical Society, 47 Belgrave Square, London, S.W.1. Those interested in offering short contributions should write immediately to Dr. M. J. Stowell, T.I. Research Laboratories, Hinxton Hall, Saffron Walden, Essex.

Notes and News

Admiralty Surface Weapons Establishment

Presentation of Prizes to Apprentices

The annual presentation of prizes to craft apprentices took place on Thursday, 6th March when Mr. J. W. Snowdon, M.B.E., presented the following prizes.

M. E. Kiel	1st Year	1st Prize	R.N.S.S. Award
P. Skeens	2nd Year	2nd Prize	R.N.S.S. Award
R. McCarthy	2nd Year	1st Prize	R.N.S.S. Award and Cup
P. G. Perrett	3rd Year	1st Prize	Artificers Award and Cup
D. Evans	4th Year	2nd Prize	R.N.S.S. Award
V. Young	1st Year	2nd Prize	R.N.S.S. Award
P. Kerry	4th Year	1st Prize	Laboratory Mechanics Award and Cup

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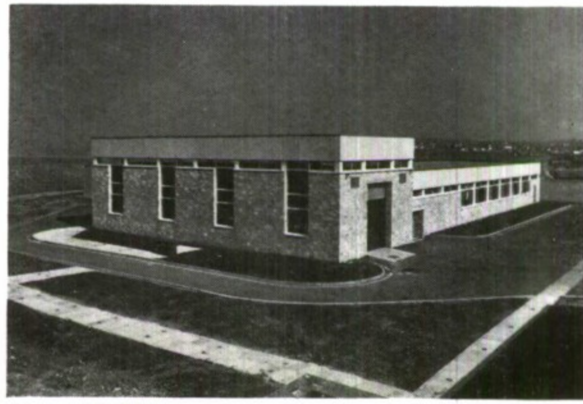
Admiralty Underwater Weapons Establishment

At A.U.W.E.(S) Portland a new torpedo assembly shop has been built to provide the necessary facilities for the assembly and functional testing of present and future types of torpedoes or underwater weapons for use in the R.N.

The building, which stands some distance from the main workshops is approximately 150 ft. long by 72 ft. wide and is divided into three sections. No. 1 section is a dirty area in which torpedoes are dismantled after trials and prior to cleaning and modifying as required. There are ultrasonic cleaning facilities available, and after cleaning, components are bagged and sealed until required. In this area there is a trimming tank 30 ft. by 3 ft. 6 in. by 5 ft. deep, also a pressure test vessel 30 ft. long by 2 ft. 4 in. in diameter and fitted with observation windows, for simulating depth pressures of up to 1,500 feet. Also in No. 1 section are small workshop ancillaries such as band saw, drilling machine and lead bath for casting ballast weights.

A three ton travelling crane is available for lifting purposes.



View of building.

No. 2 section is entered by an air lock and is in the dust controlled area of 20 microns. This section is used for the assembly of hydraulic systems gyro testing and running, testing of contraction and control units.

No. 3 section is used for the assembly and functional testing of all types of torpedoes.

In areas 2 and 3, the temperature and humidity is controlled, the temperature at 65°F ± 5°F and the humidity not to exceed 65% RH. The air is filtered through 20 micron nominal filters with a + ve pressure of not less than 0·5 in. of water above atmosphere, also provision is made for cooling the hydraulic test console and various types of torpedo test sets.

The new torpedo workshops

Windows in the dust restricted areas, are double glazed, all doors subject to air locks. The artificial lighting is of high illumination level and is totally enclosed behind the false ceiling. There are built-in vacuum points for hose connections for cleaning purposes. The floor is covered by an " Epikote " resin-based coating and is impervious to oil, all the main services are in ducts under the floor. Benches are covered with Formica, and supports painted with high gloss paint. Lint free clothing is worn by all personnel working in these areas. A changing room with lockers for outdoor clothing, a mess room, toilets and washing facilities are provided.

Mr. J. R. A. Jones attended the International Conference on Remote Data Processing at the UNESCO building in Paris during March, from which it became apparent that there will be a very rapid increase in data transmission telecommunication networks over the next few years. A paper by Mr. Jones, entitled "A Language Common to Machine Drawing and Machine Tools " has been accepted for reading at the forthcoming International PROLAMAT Conference on programming languages for machine tools.

Mrs. B. Hesketh of the Scientific and Technical Information centre attended a course in " Systems analysis for Libraries and Information Centres " at Bristol University, and Mr. W. Humphries of the same department an "Advanced introductory course on Information Services " at ASLIB, recently.

The Information Centre at AUWE has started experimental work on the mechanisation of report records using punched paper tape as the medium of data storage. It is intended to produce a series of reports detailing methods used, reasons for their use and reasons for any deterioration of the proposed method which may take place. An investigation is being conducted into the classification and filing systems used in the information centres of the Navy Dept. A questionnaire has been issued by the Information Officer at AUWE to all such organisations to collect the required information.

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Admiralty Experiment Works

In March, A.E.W. was visited by Mr. Morton Gertler from N.S.R.D.C., U.S.A., and Professor K. Nomoto of Osaka University, Japan, who later accompanied Mr. A. J. Vosper (Superintendent A.E.W.), to Vienna to attend the meeting of the I.T.T.C. Mr. J. E. Conolly gave the paper " Sea Trials of Anti-Pitching Fins " jointly with Mr. G. J. Goodrich at the Spring Meeting of the R.I.N.A.

Dr. A. Lloyd attended the Polaris firing trials of H.M.S. *Repulse*, in April at Port Canaveral, U.S.A. Also in April, A.E.W. was visited by Mr. S. Thulin of the Swedish Tank for whom some model testing is being carried out at A.E.W. He remained for the three-day international Planar Motion Mechanism course.

Visitors to A.E.W. during May included members of the West of England Branch of Marine Engineers, the Senior Officers War Course, Naval Attaches from a number of countries in connection with the Naval Underwater Engineering Equipment Week, and representatives from N.S.R.D.C., Mr. J. Strom Tejsen, Mr. G. Stuntz and Mr. J. Luisho, for discussions on Sonar Array Research. Also in May, the lecture given by Mr. A. Woodroff of the Meteorological Office on " Weather Routing of Ships " at N.P.L., Ship Division, Feltham, was attended by Mr. R. F. Lofft and Miss W. E. Bolton.

International P.M.M. Course, A.E.W., 21st - 23rd April, 1969.

The three day course held at A.E.W. to mark the commissioning of the first Planar Motion Mechanism (P.M.M.) in U.K. was oversubscribed. The thirty participants included representatives from Denmark, Greece, Holland, Japan, Sweden, West Germany and the U.S.A. The course was intended to educate shipbuilding interests in U.K. in the use (and abuse) of the P.M.M. as a tool for the study of ship and submarine stability and control. The use of the P.M.M. to obtain oscillatory coefficients, and the possibilities of applying P.M.M. techniques to non-linear equations were particularly interesting. The lectures were given by Professor Bishop and Dr. Parkinson of University College London, Mr. Vosper (Superintendent), Messrs. Booth, Burcher, Chislett, Driscoll, Simmonds, Tee of A.E.W. Presentations were also made by Mr. Fujii (Japan), Professor Newman (U.S.A.), Mr. Wagner Smitt (Denmark), Messrs. Glansdorp and Van Leuwen (Holland).

Advantage was taken of the presence of the Danish visitors to discuss an advanced design of P.M.M. suitable for surface ship testing, to complement the A.E.W. P.M.M. which is for submarine testing. It is likely that big-amplitude P.M.M's to a common design will be installed at the Hydrodynamic Laboratory, Lyngby and at A.E.W.

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Admiralty Oil Laboratory

On 18th March, 1969, the Navy Department Fuel and Lubricants Advisory Committee (NAFLAC) met at A.O.L. and took the opportunity to walk round the new premises.

Dr. W. Petrie, Chief of the Canadian Defence Research Staff, London, and his deputy, Dr. H. P. Tardif, visited A.O.L. on Wednesday, 5th March to discuss work on tribology and related subjects. On 24th April, Mr. J. B. Allen, Head of the Canadian Defence Research Establishment Atlantic and Mr. C. W. Reyno from the same laboratory came to discuss fuels and lubricants and were particularly interested in the instrumental analysis methods in use.

Mr. R. P. Langston, Superintendent, A.O.L., attended a meeting of the Lubricants Committee of the Co-ordinating European Council for the Development of Performance Tests for Lubricants and Engine Fuels (C.E' in Gothenburg, on 22nd and 23rd April, 1969. Mr. C. E. Carpenter attended the fourth meeting of the European Standards Co-ordinating Committee Working Group 19 —Methods of Tests for Petroleum Products (CEN/WG 19) in Milan on 15th-18th April, 1969. Both attended as Ministry of Defence representatives in U.K. National Delegations.

Dr. T. D. Brown of Sheffield University and Mr. J. Ritchie of A.O.L. have been awarded the Lubbock-Sambrook Award of the Institute of Fuel for their paper " Fuel oil ash deposition in Naval boilers ", presented at the Institute of Fuel Symposium last year. This arose from a Navy Department Research Contract on which Dr. Brown was working and related work by Mr. Ritchie at A.O.L.

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Central Dockyard Laboratory

On 16th April a party of overseas delegates from Canada, Australia, New Zealand, and U.S.A., who were attending the Conference, visited H.M. Dockyard, Portsmouth. The visitors were received by the Commander in Chief, Admiral Sir John Frewen, K.C.B., on board H.M.S. *Victory*, and then visited the Central Dockyard Laboratory and the Exposure Trials Station at Eastney. A visit was also arranged to H.M.S. *Devonshire* and H.M.S. *Falmouth* to view demonstrations of cleaning, preparation, and protection of steel plating.

Overseas delegates on board H.M.S. Victory

The meeting of the Permanent International Committee for Research on the Preservation of Materials in the Marine Environment was held in Genoa on 27th-29th March 1969. Dr. E. N. Dodd and Mr. D. R. Houghton who are Chairman of the Underwater Protectives Coating and Biology Groups respectively, represented C.D.L. at the meeting.

On 19th March 1969, Mr. B. N. Hall gave a lecture on Marine Corrosion to M.Sc. Students at the University of Southampton.

The following papers were presented by members of the Central Dockyard Laboratory Staff at the Third Inter-Naval Corrosion Conference held in London from 14th-18th April:—

"Further problems on the development and application of effective anti-corrosive paint systems".

By J. Smith (C.D.L.) and C. A. S. Palmer (D.G. Ships, Bath).

"The chemical and biological basis for the development of black anti-fouling paint".

By E. T. Wilkie and D. R. Houghton (C.D.L.)

"Development and fabrication of copper based alloys for marine use".

By J. N. Bradley, G. Newcombe (C.D.L.) and J. M. Short (A.M.L.).

"Factors to be considered in the choice of cathodic protection for ships."

By C. A. S. Palmer (D.G. Ships, Bath) and D. A Chapman (C.D.L.).

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Services Electronics Research Laboratory

Messrs. L. N. Large and M. Hillier have transferred to C.V.D. for a period of detached duty.

Mr. R. Redstone attended a conference on 'Organization and Management of Research and Development' in London on May 5th.

Messrs. L. Clough, P. Gurnell, M. C. Rowland and G. P. Wright attended a meeting in Paris of the Anglo-French Working Group on Valves and Semiconductors and visited several laboratories concerned with valve and semiconductor research and development.

Mr. P. D. Lomer visited the U.S.A. during the period 25th May to 10th June in order to attend an I.E.E.E. Conference in Washington, a U.K./U.S. technical liaison meeting, and to visit a number of research laboratories.

Mr. R. M. Allen attended the 'International Symposium on Ion Sources' in Paris and visited research laboratories in Paris and Grenoble.

Dr. C. H. Gooch visited the U.S.A. in June to attend the 'Solid State Devises Research Conference' at Rochester and to visit several firms.

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Books available for Review

Offers to review should be addressed to the Editor

Digital Computers—A Practical Approach.
2nd Edition.
I. P. Marchant and D. Pegg.
Blackie and Son Ltd. 1969. 30/-. (No. 1734).

Mass Spectrometry and Ion-Molecule Reactions.
P. F. Knewstubb.
Cambridge University Press. 1969. 40/-. (No. 1735).

Stochastic Approximation.
M. W. Wassan.
Cambridge University Press. 1969. 70/-. (No. 1736).

Electrical Principles.
Watkins and Jones.
Blackie and Son Ltd. 1969. 9/6. (No. 1737).

Statistical Methods for Engineers.
J. J. Leeming.
Blackie and Son Ltd. 1969. 20/-. (No. 1738).

Basic Ideas of Abstract Mathematics.
Fyfe and Woodrow.
University of London Press Ltd. 1969. 15/-. (No. 1739).

Thermal Physics.
A. G. E. Blake.
University of London Press Ltd. 1969. 15/-. (No. 1740).

The Complete Nautical Astronomer.
C. H. Cotter.
Hollis and Carter. 1969. 63/- (No. 1741).

Newer Engineering Materials.
Edited by R. F. Winters.
Macmillan and Co. Ltd. 1969. 60/- (No. 1742).

Book Reviews

Detection, Estimation and Modulation Theory, Part I. By Harry L. Van Trees. Pp. xiv + 697. New York; London, Sydney; John Wiley and Sons Inc. 1968. Price 175s.

This book has been written by H. L. Van Trees who is an Associate Professor of Electrical Engineering at the Massachusetts Institute of Technology. The title of the book is somewhat confusing since the subject is really a treatment of signal detection. The confusion is caused by the author's classification of three types of signal and their detection. Thus, the term " detection ", to the author, implies the detection, in noise, of a signal having a number of defined states: e.g. in the simplest case, the detection of binary coded signals. The term "estimation", to the author, implies the detection, in noise, of a signal that is a sampled representation of another signal; e.g. the detection of pulse amplitude modulation, pulse position modulation etc. The term " modulation ", to the author, implies the detection of continuous waveforms or, to use the author's terminology, the " estimation of continuous waveforms ", e.g. the detection of amplitude modulation, phase modulation etc. This last classification is particularly confusing since modulation is usually defined as the process by which signals control the appropriate characteristic of a carrier waveform. However, having accepted this confusion, the reader will find that the main text contains an extensive treatment of detection processes. The treatment is not complete as there is another volume notated as Part II which, apparently, is completely integrated in subject matter, with Part I. Part I is based on notes prepared for lectures and is intended for students who have completed a graduate course that has included a study of such classic works as Davenport and Root's " Random Signals and Noise ". However, the author states that the mathematical background is such that practising engineers, with a knowledge of elementary probability theory, will find the book useful.

The contents of Part I can be outlined as follows:

Chapter I is an introduction in which the author introduces his classification of detection processes. Chapter II is concerned with the classical aspects of " detection and estimation " theory. Chapter III deals with the theory of the representation of random processes. Chapter IV treats the " detection " and " estimation " of various types of signals in noisy environments. Chapters V and VI deal with the " estimation " of continuous waveforms. Final sections of the book include a summary of Part I, a preview of Part II, a suggested lecture course outline based on Part I material, a glossary and extensive author and subject indices. In addition, the volume is well provided with useful references and problems for the reader. In conclusion, the treatment should be of benefit to the research worker in the signal detection process field. The book will not be of similar value to the practising engineer, mainly due to the problems introduced by the author's classification which tends to make it difficult to extract information on selected topics of interest.

H. W. Hawkes

Physics Pocket Book. Edited by H. Ebert. Edinburgh and London. Oliver and Boyd. 1967. Pp. 575, 164 diagrams, 167 tables. Price 63s.

The publishers of the Physikalisches Taschenbuch, from which the present volume is translated, appear to be misinformed about the sort of pockets readers are likely to have, and the present publishers have stuck to a translation of the German title, in spite of the fact that the volume is nearly an inch and a half thick and weighs two pounds. One comparison, however, is with the Handbook of Chemistry and Physics, which is considerably less handy in any physical sense.

The Physikalisches Taschenbuch (like the Handbook of Chemistry and Physics) did indeed start as a readily pocketable volume, but by the third edition, published in 1962, from which the present volume derives, had grown till the only value of the name was in the ample goodwill which it carried. The Physikalisches Taschenbuch, however, despite the 167 tables, never set out to be a collection of data, and it would be unreasonable to expect the English version to be one; it follows the German original exactly. It is in fact a much condensed textbook of theoretical physics in which the narrative is severely cut.

It is unfortunate that the English translation should not have appeared until five years after the German 3rd edition since in the same year as the present volume the fourth edition of the Physikalisches Taschenbuck was published, with 706 pages, and it is considerably less unpocketable than the Physics Pocketbook (the new German edition is considerably revised, lacks a chapter on the calculus of probability and has considerably expanded the section on nuclear physics. It has a considerably better index).

There are four introductory chapters of general application, on Quantities, Numerical values and units, Symbols for units and formulae, Mathematical aids and Calculus of probability, Statistics and the theory of errors of observation, after which come eight subject chapters on Theory of relativity and quantum theory, Mechanics, Acoustics, Optics, Heat, Electricity, Magnetism and electromagnetism, Atomic and nuclear physics and Strength of materials. It is perhaps surprising to find that the chapter on mathematical aids is, with the exception of that on heat, the longest in the book. The chapters or sections are produced by some 43 specialist contributors, but the editing has produced a large degree of uniformity among them; one result of the fragmentation, however, is that the tables and figures are numbered anew in each section (apart from some in which they are not numbered at all) without any reference to the section number; similarly the numerous formulae and equations are numbered in some sections but not in others.

The tables are often unsatisfying. Many of them merely give a few examples of the quantities they purport to set out and the sources of the figures are never stated; the headings are also sometimes uninformative, as in the unnumbered table on p.197 which states that " 10 molecules are present ", leaving the reader to find from the context or his own knowledge that it means that they are at present in 1 cm^3, and in the same table the source of the information that in the interior of the earth there are 10^{24} molecules (per cm^3) is of course not disclosed.

The strength of the compilation is in the equations and formulae and for the student or the worker who needs them in a field away from his own expertise. The volume provides a first-class collection and a very valuable reference book, with a text which is sufficient to introduce them and connect them together with an absolute minimum of name-dropping.

The translation is a very good one, with up-to-date terminology (and only a very few instances of using German terms for nearly identical English ones) and English phraseology. The printing is also very good; the printer's errors are few and far between, and the equations are well set out, though occasionally in the anxiety not to get into an additional line the spacing in the lines is inadequate. The price is reasonable for what it is and for those who need such a compilation (and are not expecting to get a collection of data) it is a good buy.

A. H. Holloway

A New Guide to Modern Valency Theory. By G. I. Brown. Pp. ix + 234. London. Longmans, Green and Co. Ltd. 1967. Price 21s.

Valency is a central theme in chemistry. Modern valency theory can be said to have originated with Pauling and Kossel some time after the introduction of Bohr's quantum theory. In principle modern quantum theory should be able to calculate the shapes and binding energies of molecules from first principles but this ideal which was used to taunt physical chemists after 1925 has never been realised except for a few isolated cases, for example the binding energy of the hydrogen molecule.

Nevertheless quantum theory is of immense value in valency theory, even though the results are more qualitative than quantitative. Theoreticians have usually followed two broad lines for the quantum study of molecules. These are the valence bond method and the molecular orbital method. The book under review is mainly concerned with the second method which in general has been the more widely developed of the two methods. This usually takes the form of using a linear combination of atomic orbitals as the molecular orbitals and hence the acronym L.C.A.O.

The book under review is an excellent introduction to the modern theory of valency written by a member of the staff of Eton and intended for senior grammar school pupils and first year undergraduates. It should be suitable for a much wider audience than the above, particularly to those who want to find a good introduction to a subject which is complex and mathematical at its higher levels. The author avoids the use of mathematics almost completely and the orbitals which are the basis of the L.C.A.O. method are illustrated graphically. Nowadays models of these orbitals are becoming available commercially and should do much to simplify the spatial parts of these functions. Two excellent features of the book are a formula index and the extensive use of cross-references in the text to the exact place where the argument has been or is to be developed further or an alternative interpretation is given.

The book is a complete rewrite of an early edition published about twelve years ago and consists of nineteen chapters. The main chapters deal with the types of chemical bonds, the formation and characteristics of ionic compounds. molecular orbitals, the directional nature of covalent bonds, resonance and electronegativity, hydrogen bonds, co-ordination complexes and crystal and ligand fields, and bonding in metals.

Two subjects are of great interest, the hydrogen (or proton) bond and ligand field theory, and are dealt with in the book. The hydrogen bond is of great importance for instance in biochemistry. Its exact nature has not yet been fully resolved and may be partly electrostatic and partly covalent.

Ligand field theory originated with Orgell as an extension of crystal field theory developed much earlier, mainly by Bethe, and is concerned mainly with complex ions. A large section of the book is devoted to these modern topics.

The book is full of useful information and tables such as the compounds of the noble gases, the electrochemical and spectrochemical series, bond orders, shell structure of the atoms and modern periodic tables including the new transuranic elements. It can be strongly recommended to students of chemistry.

R. A. M. Bound

Workshop Technology. By F. J. Long. 1968. Pp. 113. London; Macmillan & Co. Ltd. Price 10s.

"Why is a cold chisel so called ?" and "What is meant by the pinning of files ?"; the answer to these questions and others may be found in "Workshop Technology" by F. J. Long, which contains a large amount of information normally acquired by years of practical experience. This information is attractively presented in a very readable "Question and Answer" form, with plenty of good clear illustrations. To have this knowledge to hand at the commencement of an apprenticeship would be of immense value and the basic points covered lay the foundations for a practical engineering career.

The main sections of the book cover engineering measurement; metal cutting; metal forming; marking out; metal joining; heat treatment of steel; testing of metals and machine tools.

In my opinion, the only weaknesses of this useful little book relate to the metal joining section—which hardly does justice to soldering and welding—and a total disregard of the coming metric system of measurement.

M. Swan

Examples and Exercises in 'A' Level Physics. By H. V. Pilling. Pp. vi + 123. London; The English Universities Press Ltd. Price 8s.

This book is intended to cover problems on all aspects of physics for the sixth former and for the undergraduate taking physics as a subsidiary subject. "All aspects" is rather an ambitious claim, and it is noted that electronics, as such, is not covered. The work includes 135 examples and 325 exercises taken from School Examining Boards and Universities in Britain and overseas.

The author, who is Head of the School of Science, Oxford College of Technology, has helpfully arranged the problems in sections covering the following:—Principles of Dynamics, The Dynamical Concept of Matter, Calorimetry and Temperature, Transference of Heat, Coefficients of Expansion and the Gas Laws, Characteristics of Wave Motion, Geometrical Optics, Optical Instruments, Static Electricity, Steady Currents, Electromagnetics, Alternating Current, Instruments, Magnetism, Electrical Conductivity, Atomic and Nuclear Physics, Miscellaneous, Synopsis and Glossary, Answers.

The typical examples serve both as a useful means of revision and a good introduction to the problems. The examples are well chosen but not always well balanced, e.g., there are five examples on saturated vapours, but only two on alternating current. Some of the problems and examples are nearer G.C.E. 'O' Level standard which is useful for revision purposes. The exercises originate from a variety of sources including examining bodies in Africa, Australia, Canada and New Zealand as well as the British Isles. This fact may deter those students in the final stages of revision for say, a London University Examination to whom questions set by the University of Witwatersrand may seem irrelevant. However, problems have been carefully

selected to cover the various aspects of the syllabus, no doubt in the light of experience.

It is a pity that some problems use the c.g.s. system of units which is not now favoured by many U.K. Universities.

The glossary should prove most useful, not least on the eve of the examination. The book is to be commended to both teacher and student in the fifth and sixth forms and for undergraduates such as those studying medicine who require physics as a supplementary subject.

J. F. Gallagher

Physics (2nd Edition). By Marshall, Pounder and Stewart. Pp. vii + 1139. Toronto; Macmillan of Canada; New York; St. Martin's Press, 1968. Price 60s.

This textbook is intended to cover the major branches of physics at a level suitable to an introductory course for University students in Science and Engineering. The subject matter is arranged in sections covering Mechanics, Heat, Sound, Light, Electricity and Magnetism, and Atomic Physics. Each section is divided into chapters on particular aspects. Thus the mechanics sections has chapters on: Introduction; Units of Time and Length, Kinematics, Force, Energy and Power, Friction, Angular Motion, Statics and Machines, Elasticity, S.H.M.; Gravitation, Fluid Mechanics.

It is sometimes argued that modern texts should start with a description of atomic physics which, as the authors agree, attempts with increasing success to give a unifying explanation to all the classical divisions of physics (and chemistry) in terms of sub-atomic particles. The authors have chosen to follow the classical line as more helpful to an understanding of any visible piece of matter and appeal only occasionally to atomic physics for explanations.

The four reasons underlying the revision of the earlier edition are:—

(1) The need to use the ideas, notations and language of calculus from the start so as to align with most University courses. This is done so that the student is introduced to the basic equations of Maxwell only later in the text.

(2) To reduce the space devoted to current technology though maintaining an awareness of it, because technology changes so rapidly.

(3) To include a reference to new Scientific discoveries, particularly in the section on Atomic Physics and such items as lasers and Van Allen Belts.

(4) To optimize the direct interaction between student and textbook because student schedules are now allowing enough time for study.

This is a fine work written by those who are familiar with the difficulties of the student. The style is in general clear and lucid and where practicable is simple and almost conversational, e.g. "The day is divided into 24 hours, the hour into 60 minutes and each minute into 60 seconds. (The use of these somewhat strange numbers is a heritage from the ancient Babylonians who were rather fond of the number 12)", or again regarding units, "The British system is noted for its extraordinarily large number of units and for the awkwardness of its conversion factors," page 10. The illustrations are adequate, if conventional, and the type clear and uncluttered with paragraph references.

The size of the book and the range of subjects bear witness to the "intake of information" problem confronting the student. In some cases the treatment is in excess of our 'A' Level Examination requirements, but makes very helpful supplementary reading for students at this level and the early stages of study for a first degree. The scarcity of worked examples may be seen as a disadvantage but these no doubt have had to be reduced to save space. A worked example on the "apparent weight" of a lady in an elevator having downward acceleration bears the footnote, "This is the quickest, if least permanent way to lose weight". With the present emphasis on S.I. or MKS units it is perhaps unkind of the authors to calculate the lady's mass in "slugs" however.

The division of the work into somewhat arbitrary sections occasionally causes separation of related subjects. e.g., "inductance" is discussed under the chapter on Electromagnetic Induction and again in a later chapter on alternating currents, but the texts are not cross-referenced and the index refers only to the chapter on Induction. Similarly a transistor is briefly described under Electronics without reference to the basic properties of a transistor described under the chapter on Electricity and Magnetism (though here the index comes to our aid).

In general, however, the authors have succeeded in their aim to provide a maximum of enlightenment and a minimum of misunderstanding.

An Appendix is included covering Atomic Weights, the Periodic System, Systems of Units, Differentials, Exponentials and Logarithms.

Answers are given to the odd-numbered problems only.

J. F. Gallagher

Computing Methods for Scientists and Engineers. By L. Fox and D. F. Mayers. Pp. xii + 255. Oxford; Clarendon Press; 1968. Price 45s.

This book is the latest publication stemming from the summer schools organized by the Delegacy of Extramural Studies and the Computing Laboratory at Oxford University. It may be considered to be a handbook or reference book of practical computing methods since theoretical results are accepted without proof and the mathematics involved is essentially elementary.

Chapters 1, 2 and 3 cover the topics of problem formulation and choice of method, error analysis and floating-point arithmetic and computations with recurrence relations respectively and form the necessary basis for the following chapters concerning computations with polynomials and matrices, polynomial and Chebyshev approximation. These chapters outline their respective procedures with particular reference to problems of instability both inherent and induced to enable the reader to solve problems with the best likely accuracy.

Chapter 8 outlines interpolation and differentiation, finite differences and Lagrangian methods and is followed by a chapter on numerical integration.

Ordinary differential equations are discussed in Chapter 10 with particular emphasis on inherent instability and initial value problems, treatment of truncation error, induced instabilities and boundary value and eigen value problems.

Each chapter succeeding the introductory chapters exists satisfactorily as an entity in itself which is the reason one may consider the work as a reference handbook and each chapter is supported by a list of relevant exercises.

The book is concluded by a Bibliography of some 30 references to allied and supporting material and the book may find a useful place in the personal libraries of many practising scientists and engineers.

D. Robson

Matrices, Their Meaning and Manipulation. By W. G. Bickley and R. S. H. G. Thompson. Pp. xiii + 168. London; The English Universities Press Ltd., 1968. Price 20s.

The first part of this book is designed as an introduction to the idea of a matrix and to elementary matrix algebra. The first chapter gives a few relevant worked examples in the formulation of matrices representative of sets of simultaneous equations. Chapter 2 describes matrix notation and precedes chapters describing matrix multiplication, special matrices, applications of matrix products and determinants respectively.

These first six chapters are intended to cover almost all the introductory work but it is felt however, that perhaps the authors expect the reader to have somewhat more experience in the field of matrix notation and manipulation than they would have one believe in the preface. These introductory chapters may serve a useful purpose as a revision course to precede the bulk of the book.

Chapter 7 deals with the solutions of systems of linear equations as illustrations of elementary matrix manipulation before proceeding to the numerical solution of these equations and evaluation of determinants in Chapter 8. This chapter on numerical solution is perhaps the most useful as far as the practising engineer is concerned.

Chapters 9 and 10 are concerned with Eigen-Values and Eigen-Vectors and their numerical determination respectively and may be considered as a sound treatise of this topic.

Each chapter is concluded by a list of relevant exercises, the answers to which appear at the end of the book.

Considered as a whole, the book is a useful and illuminating treatise of matrices and matrix algebra for a student or engineer with a little basic knowledge of matrices.

D. Robson

Research Frontiers in Fluid Dynamics. Edited by R. J. Seeger and G. Temple. Pp. ix + 738. John Wiley and Sons, Inc. London and New York. Price 230s.

Here is a welcome change from the run of standard text-books on fluid dynamics offering successive versions of the same basic theory over and over again, each giving the impression that the whole subject has been neatly tied up. This book is a most interesting addition to the literature from which the student can appreciate that here is a living subject. In discussing recent developments the authors have not been afraid to report difficulties in achieving solutions to particular problems, indicating where success has in some places not yet been achieved. Quite often the likely directions of future developments are suggested, something that scientists are sometimes reluctant to divulge when they themselves are involved.

Experts in their various fields present twenty papers on theoretical advances over a very wide front. It is apparent that the editors have not attempted to impose a standard type of presentation from their various contributors. At one end of the scale is a self-contained paper (24 pages) on a particular problem—*Asymptotic Solutions in Hypersonic Flow: An Approach to Second-Order Solution of Small-Disturbance Theory* by N. C. Freeman. At the other extreme is a comprehensive survey—*Free-Surface Flows* by J. V. Wehausen, running to 70 pages plus a bibliography of 36 pages. This covers gravity waves, both irrotational and with vorticity, and irrotational flows without gravity (jets and cavities) discussing both exact and approximate methods of solution. Naturally included are waves from ships and the effect of beaches, together with shallow water theory and other approximations.

Another contrast exists between the presentation of *Meteorology* and of *Oceanography*. The former by O. G. Sutton offers a brief descriptive account of three topics, numerical weather forecasting, general circulation of the atmosphere and micrometeorology, and reference is made to a number of other accounts if the reader wishes to gain a closer understanding of the methods of solution. In contrast *Oceanography* by A. R. Robinson discusses only large scale steady motions, derived from wind or thermal driving or both, but gives a fairly detailed mathematical exposition.

Two of the papers appeared to the reviewer to fall into a different category from the rest, being concerned with their particular disciplines. *Mathematical Aspects* by M. H. Rogers *et al.* discusses in considerable detail the method of singular perturbations, with the matching of solutions as in boundary layer theory and Lighthill's uniformly valid solution, with applications to a number of particular problems. *Numerical Analysis* by H. Polachek considers primarily the numerical solution of partial differential equations by the method of finite differences. Apart from these two chapters the others divide into particular problem areas with, where appropriate, an inter-disciplinary approach.

There are four chapters on basic fluid theory, *Molecular Theory of Fluids* by H. S. Green, a systematic account of the main achievements, *Viscoelastic Fluids* by R. S. Rivlin, the formulation of the constitutive equations in a relatively new subject, *Anomalous Viscosity* by M. Reiner, where the viscosity depends on the velocity gradient, and *Second-Order Effects,* again by M. Reiner.

On various aspects of aerodynamics there are a number of papers. The very first chapter has the wide, somewhat misleading, title of *Engineering Aspects* (W. R. Hawthorne) while concentrating entirely on the theoretical solution to the shear flow round pipe bends and the effect of wall friction. *Shockwave Phenomena* by D. C. Pack gives a general summary of the structure and behaviour of shock waves, discussing also blast waves, combustion and detonation. There follows *Transonic Flow* by K. G. Guderley, a paper on hypersonic flow already referred to, and *Magnetofluid Dynamics* by C. K. Chu and H. Grad offering a fairly complete picture of the special case for the non-dissipative fluid, *i.e.* inviscid, non-heat conducting, perfect electrical conducting fluid. *Application of the Boltzmann Equation to Low-Density Flows* by G. N. Patterson shows the Boltzmann equation providing a single unified approach linking flow properties in free molecule, transition and continuum regimes.

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It is not claimed that this book attempts a complete coverage of advances being made in all aspects of the subject. The volume had to be kept to a reasonable size and even so its price will inevitably limit the number of copies purchased by individuals. Yet this is not a book to be left on library shelves. It demonstrates so interestingly the breadth of the spectrum of research now coming under the heading of fluid dynamics.

D. L. Ryall

Van Nostrand's Scientific Encyclopaedia, 4th Edition. Pp. ix + 2008 D. Van Nostrand Company Inc. 1968. Price £18.

Van Nostrand's Scientific Encyclopaedia has been available since 1938 and each of its editions, including the present one, has maintained and improved the reputation the volume deservedly possesses for topicality and a high standard of presentation, print and diagrams. The stated purpose of the encyclopaedia is to act as a basic reference work on science, engineering, mathematics and chemistry and offer adequate coverage of all branches and disciplines of functional scientific knowledge. It further claims 'to provide the information needed by the professional, but is so simply written that it can be profitably used by any reader'. How well, then, does this single volume, containing over 2,000 pages, nearly 2½ million words spread over more than 1,600 articles, with some 2,000 illustrations and weighing 11 lbs., match up to its claims, and how genuinely useful is the present edition?

The preface itself acknowledges that selective judgement has had to be exercised in the treatment of material, and presumably also in the selection of topics, and it therefore tacitly accepts that there are omissions. The professional will obviously not be satisfied with the adequacy of the information given within his own field, but, granted that this must be the case with any encyclopedia, how well satisfied will he be with the scope of entries and depth of treatment given to topics outside his own field, and on which he may require information?

The conclusion reached by the reviewer, after applying, with the aid of colleagues, a series of random checks, spread over such diverse fields as aeronautics, computer technology, electronics, mechanical engineering, nuclear science, chemistry and metallurgy, was that the standard and scope of entries were generally sufficiently good to justify the inclusion of this volume in any general library and in most technical libraries. The professional, however, is unlikely to be completely satisfied even with entries outside his own specialized field. He will discover that there is something less than an 80% probability of finding the entry he wants, he will find that references to assist further reading on any topic are scanty, and the degree of cross referencing is not sufficiently adequate to avoid frustration setting in whilst the searcher turns from one possible key word to another in an effort to find that which he really wants, *e.g.*—Mach Number will not be found under the 'M' section, but under Compressibility (Aerodynamic). There is also a curious variation between the excellent coverage given to some entries (*e.g.* Zirconium) and the very elementary and limited coverage given to others (*e.g.* Sonar). In general, the more popular modern technological topics, such as space travel, are well covered, although one will find only a rather sparse entry under 'supersonic transport'. The chemical and materials fields are perfectly adequate, and some aspects of atomic and nuclear science are very well dealt with, although the section on nuclear reactors is limited, not too up-to-date in places, and not particularly well written.

This, then, is the general pattern; despite the extensive range of entries, there are still many gaps, and the information given will range from excellent, to extremely sparse and elementary. Nevertheless, one must not forget that these remarks would apply to most single volume encyclopediae, and the general level of information and content of this volume is certainly of a high enough standard to justify its purchase by any library.

J. Edwards

Probability. By J. R. Gray. Pp. viii + 268. Edinburgh and London; Oliver & Boyd Ltd. 1967. Price 17s. 6d.

The "University Mathematical Texts" published by Oliver and Boyd have, for many years, provided a source of excellent cheap textbooks dealing with mathematical topics. This book is a valuable addition to the range.

The early chapters deal with the basic concepts and axioms of probability calculus together with the use of generating functions and recurrence relations for solving the more involved types of discrete variate probability problem. These are followed by chapters discussing continuous variates and an examination of problems involving occupancy, runs and matching. Finally, recurrent events, renewal processes, Markov chains and processes and queueing theory are investigated.

It is claimed on the flyleaf of this book that there is an increasing need for a knowledge of probability calculus so that the statistical analysis of numerical results can be correctly applied and properly undertood. In view of this, it is a pity that the treatment of continuous variate probability distributions, on which many statistical methods are based, is so brief. However, the inclusion of a comprehensive treatment of this subject would have led inevitably to the exclusion of a number of the topics treated in the later part of the book, many of which have practical interest.

Most of the topics discussed are presented clearly and concisely, and the book is well planned. It should prove to be of considerable value to students of mathematics and is good value for money.

R. G. F. Taylor

Quantum Mechanics. By R. A. Newing and J. Cunningham. Pp. ix + 225. Edinburgh and London; Oliver & Boyd Ltd. 1967. Price 17s. 6d.

This book is another in the series of "University Mathematical Texts" and is intended to provide an up-to-date mathematical theory of quantum mechanics suitable for postgraduate and final year honours students of mathematical physics.

After a brief introduction, which comments upon the dual nature of electromagnetic radiation, the authors introduce the concept of linear vector spaces. The theory developed in this chapter is then used as a foundation for the rest of the work covered in the book. The second chapter gives an account of the general principles of quantum mechanics, including a discussion of the Uncertainty Principle and the Linear Harmonic Oscillator, and introduces the reader to operators such as the Creation and Annihilation operators.

The Schrödinger coordinate representation is then presented, including a treatment of the Tunnel Effect, and the Schrödinger equation is applied to the linear

harmonic oscillator and to the hydrogen atom. There is also a section dealing with Parity. A chapter on Scattering Theory includes an account of Coulomb Scattering and Resonances. The remaining chapters deal with Angular Momentum, Electron Spin, and Approximate Methods—including both steady-state and time-dependent perturbation theory and the variational method. Finally, there is a discussion of the Dirac electron, which shows how the quantum theory may be modified to take account of relativistic effects.

Each chapter contains a large number of problems and exercises, and the solutions are given at the end of the book. The topics are treated in a logical sequence so that the book can reasonably be read from beginning to end. A valuable feature of the text is that, although a basic knowledge of physics is assumed, each newly introduced term is explained and clearly defined. The whole text is written lucidly and is easy to follow.

This book should prove to be valuable to students of mathematical physics and also to the more mathematically minded experimentalists. It is good value for money.

R. G. F. Taylor

The Shapes of Molecules. By D. A. Rees. Pp. vii + 141. Oliver & Boyd. 1967. Price 7s. 6d.

One of a series of Contemporary Science Paperbacks, this little book gives an interesting and authoritative account of the behaviour of molecules both in the laboratory and in nature. It is written by a specialist who is currently engaged in research and hence gives an insight into some of the more recent developments in the field of carbohydrate polymers.

The principal theme which runs through the book is that of the importance of knowing the actual shape of a complex molecule in order to understand its chemical and biological properties. However, things in nature tend to be dynamic rather than static and a fruitful area of research is a study of the changes in molecular shape which occur under different conditions. The author shows how the application of some simple thermodynamic principles can aid the understanding of these processes. The range of topics discussed includes the shapes of simple molecules such as ethane and butane, sugars, and two chapters are devoted to an account of carbohydrate polymers. Throughout the text the author takes great trouble to explain fully the exact form of the molecules and his descriptions are aided by numerous clear illustrations.

The book is well planned and well written. Each chapter contains two Sections, A and B. Section A is written more for non-specialists and this part of each chapter may be read straight through the book without loss of continuity. The sections B are for more advanced readers and contain most of the more interesting work selected from recent research papers. All chapters contain a summary of each Section and a list of references.

This book represents good value for money and can be recommended to scientists who are interested in the subject and who have a reasonable knowledge of school organic chemistry.

R. G. F. Taylor

Magnetic Compasses and Magnetometers. By Alfred Hine. Pp. 385. Adam Hilger Ltd., 1968. Price 10 gns.

The author of this book was for many years responsible for the work of the Magnetic Section at the Admiralty Compass Observatory. He retired from the R.N.S.S. with the rank of P.S.O. in 1964 and the writing of this book was his main interest during his retirement but unfortunately he did not live long enough to see the final product.

The author's experience on design and development of compasses gained during his service career, and the details of the methods used for trials and testing as well as the use of the instrument under unusual conditions, figure prominently in the book.

Considerable development in remote indicating compasses took place during the last war, with Hine playing his part in developing the Admiralty Transmitting Magnetic Compass, and, subsequently, the gyro stabilised version. His idea of having a conducting liquid in the compass bowl to form part of a wheatstone bridge system was used for compasses for the Army, Navy and Air Force, during the last war and was the first successful marine magnetic transmitting compass. It is still in production.

New methods for the assessment of compass performance were also developed and some may still remember the compass trials carried out in H.M.S. *Cumberland* and in F.P.B's from H.M.S. *Hornet*, which involved staff, both ship's and A.C.O., in swinging ship so frequently at early and late hours of the day!

The theory and construction of a variety of remote indicating magnetic compasses are well described in the book, and include all the acknowledged methods of obtaining a signal from a magnetic device such as capacitance inductance, liquid resistance bridge and Hall effect devices. The performance of magnetic compasses in various types of vehicles and the factors which it is necessary to consider when determining the system characteristics are described. The information should be of considerable interest to all those designers of ships' automatic steering devices who give scant consideration to the compass design and environment and to those who hope to make their fortune from cheap remote indicating compasses for use in the small boat world.

For the past decade a committee has been sitting to determine the standards for sitting, manufacturing and testing of ships magnetic compasses and the resulting International Standards Organisation Recommendations are now in their final form and, except for a few controversial points, have been agreed. Many of the Recommendations have been anticipated by the author, who was consulted by the committee on many aspects of good design and practise. The chapter on compass testing is unique. In view of the impending publication of these I.S.O. Recommendations which I am sure will raise many questions relative to design and testing, this book has been published at the right time. Details of the building and layout suitable for magnetic compass testing will be useful to any organisation involved in the testing to the new Standard Recommendations.

The R.A.F. have recently specified standards for compass bases, made necessary by the introduction of sophisticated navigational equipment where the compass errors are required to be a minimum. This is to ensure that no magnetic effects are introduced into the compass system from the base during the calibration swing. The details of the methods used in the magnetic surveys and the categorisation of the bases is covered in the book, although the specified limits are quoted incorrectly, an error of which the author was aware but apparently had not sufficient time to correct.

The chapter on Magnetometers, includes descriptions and uses of suspension and pivoted needle instruments and development of the inductor for use in magnetometry and Magnetic Anomaly Detection but the more sophisticated magnetometers such as the Rhubidium Vapour and Metastable Helium type are mentioned all too briefly. As interest in this field is developing in connection with geophysical and space work it would

have added to the usefulness of the book if the theory and construction of these more sophisticated instruments had been treated in greater detail.

Besides details of the current range of magnetic compasses available for Service and commercial use there is a very interesting chapter on the historical background of magnetic compasses and instruments, and it is noteworthy that attempts to develop remote indicating compasses date back to the last century. There is an extremely comprehensive bibliography, the result of much research on the part of the author. To those who are concerned with the design, development and manufacture of compass equipment, the compass adjuster and those involved with methods of measuring magnetic fields, whether in strength or direction, this book can be thoroughly recommended. It is undoubtedly destined to be a standard reference but at a cost of 10 guineas is likely to be found only on the shelves of reference libraries of colleges and learned societies.

J. L. Howard

Research Frontiers in Fluid Dynamics. Edited by R. J. Seeger and G. Temple. Pp. ix + 738. New York; John Wiley and Sons, Inc., 1965. Price 230s.

Here is a welcome change from the run of standard text-books on fluid dynamics offering successive versions of the same basic theory over and over again, each giving the impression that the whole subject has been neatly tied up. This book is a most interesting addition to the literature from which the student can appreciate that here is a living subject. In discussing recent developments the authors have not been afraid to report difficulties in achieving solutions to particular problems, indicating where success has in some places not yet been achieved. Quite often the likely directions of future developments are suggested, something that scientists are sometimes reluctant to divulge when they themselves are involved.

Experts in their various fields present twenty papers on theoretical advances over a very wide front. It is apparent that the editors have not attempted to impose a standard type of presentation from their various contributors. At one end of the scale is a self-contained paper (24 pages) on a particular problem—*Asymptotic Solutions in Hypersonic Flow: An Approach to Second-Order Solution of Small-Disturbance Theory* by N.C. Freeman. At the other extreme is a comprehensive survey —*Free-Surface Flows* by J. V. Wehausen, running to 70 pages plus a bibliography of 36 pages. This covers gravity waves, both irrotational and with vorticity, and irrotational flows without gravity (jets and cavities) discussing both exact and approximate methods of solution. Naturally included are waves from ships and the effect of beaches, together with shallow water theory and other approximations.

Another contrast exists between the presentation of *Meteorology* and of *Oceanography*. The former by O. G. Sutton offers a brief descriptive account of three topics, numerical weather forecasting, general circulation of the atmosphere and micrometeorology, and reference is made to a number of other accounts if the reader wishes to gain a closer understanding of the methods of solution. In contrast *Oceanography* by A. R. Robinson discusses only large scale steady motions, derived from wind or thermal driving or both, but gives a fairly detailed mathematical exposition.

Two of the papers appeared to the reviewer to fall into a different category from the rest, being concerned with their particular disciplines. *Mathematical Aspects* by M. H. Rogers *et al.* discusses in considerable detail the method of singular perturbations, with the matching of solutions as in boundary layer theory and Lighthill's uniformly valid solution, with applications to a number of particular problems. *Numerical Analysis* by H. Polachek considers primarily the numerical solution of partial differential equations by the method of finite differences. Apart from these two chapters the others divide into particular problem areas with, where appropriate, an inter-disciplinary approach.

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Illustrations are in most cases a desirable addition. Photographs should be of good quality, glossy, unmounted, and preferably between two and three times the size of the required final picture. Graphs and line drawings should be made on a similar large scale, with bold lines to permit reduction in block making.

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